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Operations Research Society of America

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BULLETIN

OF THE

Operations Research Society of America

Supplement 1 OPERATIONS RESEARCH Volume 14, 1966

Program of the Twenty-ninth National Meeting

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THE LOS ANGELES MEETING

REGISTRATION INFORMATION

Registration

The registration desk will be located on the first floor of the Miramar Hotel (in Santa Monica, California). The hours for registration are:

Tuesday, May 17	7:00 PM to 9:00 PM
Wednesday, May 18	8:00 AM to 5:00 PM
Thursday, May 19	8:15 AM to 4:30 PM
Friday, May 20	8:30 AM to 2:00 PM.

Persons who have prepayed the registration fee and for special events can pick up their material at the registration desk. The fees are

Registration, ORSA Member	$15.00
Registration, Not ORSA Member	$20.00
Registration, Full Time Student	$3.00
Tahitian Luncheon, Wednesday	$4.00
Banquet (Prime Rib)	$6.50
Luncheon, Friday	$3.00

There will be a no-host Mixer on Wednesday evening, and a Cocktail Party (likely no-host) preceding the Banquet on Thursday evening. As is customary, except for a few designated official guests, all attendees are expected to register and pay the established fee. This includes speakers, panel members, and session chairmen.

This meeting may be very large, so advance payment of the registration fee and for special events is strongly encouraged. Otherwise, irritating queuing situations may occur. Prepayment for the Wednesday Tahitian Luncheon is especially important, since a guarantee of number of places must be made the previous day. A form for advance payment is enclosed. Please pay only by check or money order (made out to 29th National ORSA Meeting). The forms and prepayment are to be sent to Dr. John E. Walsh, 29th ORSA Meeting, System Development Corporation, Santa Monica, California.

Accommodations

The Miramar Hotel has blocked off 225 rooms for this meeting. The daily rates for these rooms are: Single $10.00; Twin $15.00; Suite (3 persons) $25.00; and Suite (4 persons) $30.00. Additional hotel rooms are available within short walking distance of the Miramar. The Ocean Palms, Shangri-La, and Oceana have about the same rates as the Miramar. The AutoMotel, Breakers, Pacific Sands, and Travelodge are nearby motels with somewhat lower rates.

Transportation

There is direct limousine (Airportransit) service from the Los Angeles International Airport to the Miramar Hotel. The hotel is not far from the airport.

COMMENTS ON PROGRAM

In keeping with the Expanding Horizons theme, this meeting contains a widely varied technical program. A special feature is the sponsorship of many sessions by the Transportation Science, Cost-Effectiveness, and Military Applications sections of ORSA. Also, several papers have authors from outside of North America. This program, which encompasses 42 sessions, is by far the largest for a national ORSA meeting. In fact, this is second largest number of sessions for an operations research meeting. The program is the largest for any operations research meeting with respect to number of participants in sessions.

LADIES EVENTS

The Santa Monica and Los Angeles vicinities offer many attractions. In addition, a tour of Los Angeles County Museum of Art has been arranged for the afternoon of Thursday, May 19. This tour will accommodate 50 persons and is free of charge (sponsored by the meeting). The places on this tour will be reserved on a first-come first-served basis. All reservations must be made in person. The tour will depart from the Miramar Hotel at noon and will return at about 4:00 PM.

COPIES OF PAPERS

Requests for copies of papers, also for information about the papers, should be made directly to the authors. Their addresses are contained in the statement of their affiliation. Please do not contact any of the committee for the meeting, the session chairmen, or the Editor of *The Bulletin* about the papers that are presented. Also, panel members should be contacted directly about their discussions.

LENGTH OF PAPERS

Invited papers are designated with an asterisk in the program. Ordinarily, invited papers are scheduled for 30 minutes, with an additional 10 minutes for discussion. Contributed papers are scheduled for 10 minutes with an additional 5 minutes for discussion. The program is rather tightly scheduled, and all authors are urged to stay within their time allowance.

DESIGNATION OF SESSIONS AND PAPERS

Abbreviations are used to identify the technical sessions and papers in these sessions. The first letter denotes day of the week, and is W, T, or F. The second letter denotes AM or PM, and is A or P. A number from 1 to 7 occurs next, and identifies which of the seven simultaneous sessions is being considered, including the room for the session. Here, 1 denotes the Satellite-East room, 2 the Satellite-

West room, 3 the Satellite-Center room, 4 the Aviation-East room, 5 the Aviation-West room, 6 the California room, and 7 the Jupiter-Venus room. Finally, following a period, the last member identifies the location (ordinarily of a paper) within the session. When the entire session is a panel discussion, the period and following number do not occur.

To illustrate this abbreviated identification procedure, consider TP3.2. This designates the second paper in session 3 (located in the Satellite-Center room) on Thursday afternoon.

The two luncheons and the banquet are also meeting sessions. The Wednesday luncheon is session WPL, the Banquet is TPB, and the Friday luncheon is FPL.

COMMITTEE FOR LOS ANGELES MEETING

Meeting Chairman and Arrangements Chairman	John E. Walsh *System Development Corporation* *Santa Monica, California*
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Assistant Arrangements Chairman	John J. Stuart *Space and Information Systems Division* *North American Aviation, Inc.* *Downey, California*

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WA3	Transportation Science Section I: Contributed Papers	9:00–Noon	Satellite-Center
WA4	Economic Applications	9:00–Noon	Aviation-East
WA5	Queuing, Bayesian, and Other Probabilistic Results	9:00–Noon	Aviation-West
WA6	Management and Product Applications	9:00–Noon	California
WA7	Gaming and Programming, I	9:00–Noon	Jupiter-Venus

WEDNESDAY, MAY 18 PM

WPL	Tahitian Luncheon	12:15–1:45	Satellite-East
WP1	Military Applications Section II, Panel On: Military Operations Research—Where Should it be Done?	2:15–5:00	Satellite-East
WP2	Traffic and Transportation Planning	2:00–5:00	Satellite-West
WP3	Research and Development in Management Operations	2:00–5:00	Satellite-Center
WP4	Flight Operations Planning for Manned Space-Flights	2:00–5:00	Aviation-East
WP5	Statistical Applications	2:00–5:00	Aviation-West
WP6	Cost-Effectiveness Section I: Aerospace Applications	2:00–5:00	California
WP7	Health, Welfare, and Socio-Economic Developments	2:00–5:00	Jupiter-Venus
——	Military Applications Section: Business Meeting	5:00–5:30	Satellite-East
——	No-Host Mixer	6:00–7:30	Satellite Area

THURSDAY, MAY 19 AM

TA1	Transportation Science Section II: Airline Applications	9:00–11:30	Satellite-East
TA2	Cost-Effectiveness Section II: Applications to Non-Military Government Problems, Part I	9:00–11:30	Satellite-West
TA3	Operations Research in the Medical Field	9:00–11:30	Satellite-Center
TA4	Planning Applications	9:00–11:30	Aviation-East

Session (Event)	*Title*	*Time*	*Room*
TA5	Military Applications Section III: Logistics	9:00–11:30	AVIATION-WEST
TA6	Optimization and Analysis	9:00–11:30	CALIFORNIA
TA7	Inventory Control and Statistics	9:00–11:30	JUPITER-VENUS
——	ORSA Business Meeting	11:30–Noon	SATELLITE-EAST
	THURSDAY, MAY 19	**PM**	
TP1	Transportation Science Section III: General Applications	2:00–5:00	SATELLITE-EAST
TP2	Cost-Effectiveness Section III: Applications to Non-Military Government Problems, Part 2	2:00–5:00	SATELLITE-WEST
TP3	Logistics	2:00–5:00	SATELLITE-CENTER
TP4	Modeling, Simulation and Computer Languages	2:00–5:00	AVIATION-EAST
TP5	Operations Research and the Behaviorial Sciences	2:00–5:00	AVIATION-WEST
TP6	Uses of Operations Research in Banking	2:00–5:00	CALIFORNIA
TP7	Military Applications Section IV: Tactics	2:00–5:00	JUPITER-VENUS
——	Transportation Science Section: Business Meeting	5:00–5:30	SATELLITE-EAST
——	Cocktail Party	6:00–7:30	SATELLITE AREA
TPB	Banquet	7:30–9:00	SATELLITE
	FRIDAY, MAY 20	**AM**	
FA1	Panel On: Computers and Operations Research	9:00–11:45	SATELLITE-EAST
FA2	Panel On: Measuring the Effectiveness of our Military and Political Effort in Viet Nam	9:00–Noon	SATELLITE-WEST
FA3	Cost-Effectiveness Section IV: Transportation Applications, Part 1	9:00–Noon	SATELLITE-CENTER
FA4	Development Assistance: A Challenge for Analysis	9:00–Noon	AVIATION-EAST
FA5	Linear Programming Results	9:00–Noon	AVIATION-WEST
FA6	Panel On: The Operational Relevance of Mathematical Programming Models for Financial Planning and Capital Budgeting	9:00–Noon	CALIFORNIA
FA7	Missile and Space Applications	9:00–Noon	JUPITER-VENUS

Session (Event)	*Title*	*Time*	*Room*
	FRIDAY, MAY 20	**PM**	
FPL	Luncheon	12:15–1:45	SATELLITE-EAST
FP1	Cost-Effectiveness Section V: Can Cost Effectiveness of Military R & D be Measured?	2:15–5:00	SATELLITE-EAST
FP2	Cost-Effectiveness Section VI: Transportation Applications, Part 2	2:00–5:00	SATELLITE-WEST
FP3	Analytical Techniques	2:00–5:00	SATELLITE-CENTER
FP4	Military Applications Section V: General Developments	2:00–5:00	AVIATION-EAST
FP5	Gaming and Programming, II	2:00–5:00	AVIATION-WEST
FP6	Papers on Planning and on Research and Development	2:00–5:00	CALIFORNIA
FP7	Applied Automation	2:00–5:00	JUPITER-VENUS

PROGRAM

of the

TWENTY-NINTH NATIONAL MEETING

of the

OPERATIONS RESEARCH SOCIETY OF AMERICA

WEDNESDAY AM, MAY 18 SATELLITE-EAST ROOM

Session WA1: 9:45–11:45 AM

Panel On: The U.S. Space Program—An Assessment And A Prognostication

Chairman: RAOUL J. FREEMAN
General Electric Company, 570 Lexington Avenue, New York, New York.

PANEL MEMBERS:

MAJOR GENERAL DAVID M. JONES, *National Aeronautics and Space Administration, Washington, D.C.*

L. L. KAVANAU, *Space and Information Systems Division, North American Aviation, Downey, California.*

ARTHUR W. ROBINSON, JR., *Missile and Space Division, General Electric Company, Philadelphia, Pennsylvania.*

ARTHUR L. SHEF, *Missile and Space Systems Division, Douglas Aircraft Company, Santa Monica, California.*

CHARLES S. SHELDON, II, *National Aeronautics and Space Council, Executive Office of the President, Washington, D.C.*

(Abstract WA1 contains an outline of the subject matter for this panel discussion.)

WEDNESDAY AM, MAY 18 SATELLITE-WEST ROOM

Session WA2: 9:00 AM–Noon

Military Applications Section I: Air Warfare

Chairman: GEORGE L. ARNOLD
Systems Research, Lockheed-California Co., Burbank, California.

WA2.1 ***Air Defense War-Game Model of the Japanese Air Defense Force,** KAZUO IMAMURA, *Operations Analysis Group, Japanese Air Defense Force Tokyo, Japan.*

WA2.2 **Evaluation and Optimization of Tactical Aircraft Avionics—Statement of the Problem and Approach to the Solution,** H. G. LUSTIG *and* P. SCHWARTZ, *Hughes Aircraft Company, Culver City, California.*

WA2.3 **Evaluation and Optimization of Tactical Aircraft Avionics—Air-to-Air Models,** J. PRATT *and* F. MOLONEY, *Hughes Aircraft Company, Culver City, California.*

WA2.4 **Evaluation and Optimization of Tactical Aircraft Avionics—Forward Looking Air-to-Ground (FLAG) Model,** D. L. LAFFERTY, *Hughes Aircraft Company, Culver City, California.*

WA2.5 **Evaluation and Optimization of Tactical Aircraft Avionics—Selection of Preferred Alternatives by the Use of Linear Programming and Coefficient Models,** R. M. MCINTYRE *and* N HANSEN, *Hughes Aircraft Company, Culver City, California.*

WA2.6 **Evaluation and Optimization of Tactical Aircraft Avionics—Computerized System Design Optimization,** J. A. STEMBER *and* P. C. LIEB, *Hughes Aircraft Company, Culver City, California.*

WA2.7 **A Dynamic Model of Tactical Air Warfare,** E. BRODHEIM, I. HERZER, *and* L. RUSS, *Columbia University, School of Engineering and Applied Science, New York 27, New York.*

WA2.8 **Air-to-Air Combat Analysis Model,** R. L. BLINKENBERG, *Lockheed-California Co., Burbank, California.*

WA2.9 **Strategic Aircraft Weapon Allocation and Force Sizing Models,** SAMUEL C. COLWELL, *The Boeing Company, Seattle, Washington.*

WA2.10 **Battle Space Exhaustion Analysis,** L. R. WHITE, *The Boeing Company, Seattle, Washington*

* An asterisk identifies an invited paper.

WEDNESDAY AM, MAY 18 SATELLITE-CENTER ROOM

Session WA3: 9:00 AM–Noon

Transportation Science Section I: Contributed Papers

Chairman: ERNEST KOENIGSBERG
Matson Research Corp., 215 Market St., San Francisco, California.

WA3.1 **The Shortest Route Problem Under Either Concave or Convex Shipping Costs,** WILLARD ZANGWILL, *University of California, Berkeley, California.*

WA3.2 **Integer Programming Methods Applied to an Air Transport Problem,** ERIC LEESE, *Canadian Forces Headquarters, Operational Research Division, Ottawa 4, Ontario, Canada.*

WA3.3 **Finite-State Machine Models of Traffic Systems,** LUCIEN DUCKSTEIN, *The University of Arizona, Tucson, Arizona.*

WA3.4 **The Tradeoff Between Lives and Driving Time,** RICHARD L. GOEN, *Stanford Research Institute, Menlo Park, California.*

WA3.5 **Evaluation of Deterministic Single Land Traffic Flow Models,** ADOLF D. MAY, JR. *and* HARTMUT E. M. KELLER, *University of California, Berkeley, California.*

WA3.6 **Planning and Optimization of Maritime Operations,** ERNST G. FRANKEL, *U.S. Department of Commerce, Maritime Administration, Washington, D.C.*

WA3.7 **Aircraft Dependability Evaluation and Logistics Planning Model,** HENRY B. SORKIN, *Douglas Aircraft Company, Long Beach, California.*

WA3.8 **Mathematical Model for Estimating Queuing Characteristics Resulting from Capacity Increases,** ADOLPH D. MAY, JR. *and* HARTMUT E. M. KELLER, *University of California, Berkeley, California.*

WA3.9 **The Role of Air Transportation in the Growth of Underdeveloped Nations (Brazil a Case Study),** WILLIAM E. DICKISON, *279 Blair Drive, Fairborn, Ohio.*

WA3.10 **Allocation of Transportation Units to Alternative Trips—A Column Generation Scheme With Out-of-Kilter Subproblems,** M. R. RAO AND S. ZIONTS, *United States Steel Corporation, Monroeville, Pennsylvania.*

WA3.11 **Optimum Common Carrier Terminal Locations,** ROBERT S. SCOTT *and* DAVID R. MCCULLOUGH, *New York State Office of Transportation, Albany, New York.*

WEDNESDAY AM, MAY 18 AVIATION-EAST ROOM

Session WA4: 9:00 AM–Noon

Economic Applications

Chairman: ELISABETH K. RABITSCH
Chemcell (1963) Limited, Montreal 2, Canada.

WA4.1 **Estimation of Functional Parameters in Econometric Error Models,** T. S. CHIDAMBARAM *and* Y. KURATANI, *Case Institute of Technology University Circle, Cleveland 6, Ohio.*

WA4.2 **The Relationship Between Interstate Variations in the Growth of R&D Activity,** IRA HOROWITZ, *Indiana University, Bloomington, Indiana.*

WA4.3 **A Method for Economic Comparison of Existing and Proposed Aircraft,** R. K. SCHAEFER, JR., *McDonnell Aircraft Corporation, Box 516, St. Louis, Missouri.*

WA4.4 **The Effect of Forecasting Procedure on System Response,** E. T. ALSAKER, *Lockheed-Georgia Company, Marietta, Georgia.*

WA4.5 **Generation of Economic and Social Information for Small Areas from Power Utility Data,** IVARS GUTMANIS, *Public Health Service, Third and C Streets, S.W., Washington, D.C.*

WA4.6 **Optimal Issuing Policies in Inventory Management—I,** WILLIAM P. PIERSKALLA, *Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

WA4.7 **Optimal Tax Splitting Among a Number of Tax Entities,** B. ALVA SCHOOMER, JR., *Arthur D. Little, Inc., Cambridge, Massachusetts.*

WA4.8 **Optimal Operating Policies for Stochastic Service Systems,** DANIEL P. HEYMAN, *University of California, Berkeley, California.*

WA4.9 **Optimal Design of a Stochastic System with Dominating Fixed Costs,** SATINDER K. MULLICK, *Corning Glass Works, Corning, New York.*

WA4.10 **The Application of Liapunov's Direct Method to a Problem in the Theory of Utility,** D. BOYANOVITCH, *Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York.*

WA4.11 **Optimum Strategy for Return of a Nonrandom Customer Competing with Random Arrivals,** MILTON L. SMITH, *Texas Technological College, Lubbock, Texas.*

WEDNESDAY AM, MAY 18 AVIATION-WEST ROOM

Session WA5: 9:00 AM–Noon

Queuing, Bayesian, And Other Probabilistic Results

Chairman: JACK R. BORSTING
Operations Analysis Dept., U.S. Naval Postgraduate School,
Monterey, California.

WA5.1 **Fractional Convolution of a Probability Vector,** EDWARD A. SILVER, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

WA5.2 **Optimal Bayesian Stratified Sampling by Nonlinear Programming,** RICHARD M. SOLAND, *Research Analysis Corporation, McLean, Virginia.*

WA5.3 **On Bayesian Confidence Limits for the Reliability of Redundant Subsystems Having Exponential Distribution of Life When Subsystem Tests Are Terminated at First Failure,** M. D. SPRINGER *and* W. E. THOMPSON, *GM Defense Research Laboratories, 6787 Hollister Avenue, Goleta, California.*

WA5.4 **Bayesian Strategies and Competitive Bidding,** DONALD H. WOODS, *University of California, Los Angeles, California.*

WA5.5 **The Stationary Behavior of a Time-Sharing System Under Poisson Assumptions,** B. KRISHNAMOORTHI, *System Development Corporation, Santa Monica, California.*

WA5.6 **Sequential Decision Problems: A Model to Exploit Existing Forecasters,** WARREN H. HAUSMAN, *Cornell University, Ithaca, New York.*

WA5.7 **Individual Choice Behavior and Markov Renewal Processes,** D. A. SCHRADY, *U.S. Naval Postgraduate School, Monterey, California.*

WA5.8 **Finite Source Queuing Models,** N. K. JAISWAL, *Case Institute of Technology, Operations Research Group, Cleveland 6, Ohio.*

WA5.9 **Some Applications in Relating Growth and Failure Processes,** GEORGE MICO, *Union Carbide Corporation, 270 Park Ave., New York, New York.*

WA5.10 **Cost Balancing of a Multiservice Queueing System with Nonhomogeneous Arrivals,** RONALD LESSING *and* EARL D. LOWERY, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.*

WA5.11 **On the Number of Tasks Performed by a Repairable Machine,** MECKINLEY SCOTT, *University of Alabama, University, Alabama.*

WA5.12 **Design of a Filter to Extract True Signal s(t) from f(t) = s(t) + n(t) Where f(t) is Time Series Generated by Stationary Random Process,** G. G. HINGORANI, *Northern Natural Gas Company, 2223 Dodge Street, Omaha, Nebraska.*

WEDNESDAY AM, MAY 18 California Room

Session WA6: 9:00 AM–Noon

Management And Product Applications

Chairman: Newton A. Ablahat
General Electric Co., 777-14th St., N.W., Washington, D.C.

WA6.1 **The Design of an Engineering Management Game,** M. A. Glatt *McDonnell Aircraft Corporation, Box 516, St. Louis, Missouri.*

WA6.2 **Desiderata for a Flexible Management Game,** Richard F. Barton. *School of Business, University of Kansas, Lawrence, Kansas.*

WA6.3 **The Grid Charting Technique for Management Information Systems,** Gordon Thomas Shahin, *The Ohio State University, Columbus, Ohio.*

WA6.4 **A Model for the Effectiveness of an Activity as a Function of the Personnel Rotation Policy,** J. J. Martin, *USN, Staff, Antisubmarine Warfare Force, Pacific, Fleet Post Office, San Francisco, California.*

WA6.5 **Some Entrepreneurial Demands on Quantitative Science,** Herbert Ruderfer, *Mathematical Analysis, IBM Corporation, Armonk, New York.*

WA6.6 **Business Operations in a Real-Time System,** Jerry Scott, *Southwestern Bell Telephone Company, St. Louis, Missouri.*

WA6.7 **Scientific and Engineering Manpower Projection and Cost Model,** Harvy B. Safeer, *Research Analysis Corporation, McLean, Virginia.*

WA6.8 **On the Application of a Specialized Control System for Scientific and Technical Information Centers,** Stanton E. Mintz, *Litton Industries, Van Nuys, California.*

WA6.9 **Research Note: Comments on Product Cost Optimization,** Robert B. McClellan, *24233 Welby Way, Canoga Park, California.*

WA6.10 **Product Performance Model (PPM),** Charles McCracken, *Martin Company, Orlando Division, Orlando, Florida.*

WA6.11 **The Evaluation of Potential New Product Alternatives,** Marshall Freimer *and* Leonard S. Simon, *The University of Rochester, River Campus Station, Rochester, New York.*

WEDNESDAY AM, MAY 18 JUPITER-VENUS ROOM

Session WA7: 9:00 AM–Noon

Gaming And Programming, I

Chairman: RICHARD C. SNYDER
Graduate School of Administration, University of California, Irvine, California.

WA7.1 **A Parametric Method for Solving Certain Nonconcave Maximization Problems,** KLAUS RITTER, *University of Wisconsin, Madison, Wisconsin.*

WA7.2 **Methods for the Solution of the Multi-dimensional 0/1 Knapsack Problem,** H. M. WEINGARTNER *and* DAVID N. NESS, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

WA7.3 **A Game Theoretic Approach for Approval of Engineering, Design, and System Change Proposals,** R. A. NELSON, *Vitro Laboratories, Silver Spring, Maryland.*

WA7.4 **Cutthroat Games,** STEVEN L. JORDAN, *Research Analysis Corporation' McLean, Virginia.*

WA7.5 **Multiperson Negotiation Games,** ROBERT L. SWINTH, *Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pennsylvania.*

WA7.6 **The Utilization of Linear Programming to Obtain a Long-Term Capital Expenditure and Operating and Maintenance Plan,** STUART C. HARRIS, *Anathon Inc., 11 East 36th Street, New York, New York.*

WA7.7 **Some Truncated-Enumeration Methods for Solving Integer Linear Programs,** FRED GLOVER, *University of California, Berkeley, California.*

WA7.8 **Linear Programming Solutions for Separable Markovian Decision Problems,** GUY T. DEGHELLINCK *and* GARY D. EPPEN, *University of Chicago, Chicago, Illinois.*

WA7.9 **A Sufficiency Solution of the Traveling Salesman Problem,** MILTON ASH, *E. H. Plesset Associates, 2444 Wilshire Blvd., Santa Monica, California, and* JOHN STAUDHAMMER, *System Development Corporation, Santa Monica, California.*

WA7.10 **Solving the Traveling Salesman Problem by Integer Linear Programming,** GLENN T. MARTIN, *C-E-I-R, Inc., 1180 Avenue of the Americas, New York, New York.*

WA7.11 **A Branch-Bound Algorithm for Plant Location,** M. A. EFROYMSON *and* T. L. RAY, *Esso Research and Engineering Company, Florham Park, New Jersey.*

WEDNESDAY PM, MAY 18 SATELLITE-EAST ROOM

Session WPL: 12:15–1:45 PM

Tahitian Luncheon

Chairman: ALAN J. ROWE
Graduate School of Business, University of Southern California, Los Angeles, California.

Speaker: WILCO GASICH, *Vice President and General Manager, NORAIR Division, Northrop Corporation, Hawthorne, California.*

Subject: **Operations Research—Art or Science?**

WEDNESDAY PM, MAY 18 SATELLITE-EAST ROOM

Session WP1: 2:15–5:00 PM

Military Applications Section II

Panel On: Military Operations Research—Where Should It Be Done?

Chairman: JOHN B. LATHROP
Lockheed-California Company, Burbank, California.

PANEL MEMBER REPRESENTING:

THE USER: JAMES R. MARVIN, *Naval Analysis Group, Office of Naval Research, Washington 25, D.C.*

SERVICE-INTEGRAL GROUPS: PAUL A. HOWER, *Operations Analysis Office, USAF, Washington 25, D.C.*

NONPROFIT CORPORATIONS: JOSEPH H. ENGEL, *Center for Naval Analyses, The Franklin Institute, 1401 Wilson Blvd., Arlington, Virginia.*

INDEPENDENT CONSULTANTS: GEORGE E. KIMBALL, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

INDUSTRY GROUPS: GEORGE L. ARNOLD, *Systems Research, Lockheed-California Co., Burbank, California.*

UNIVERSITIES: GEORGE E. NICHOLSON, JR., *Department of Statistics, University of North Carolina, Chapel Hill, North Carolina.*

(Abstract WP1 contains an outline of the subject matter for this panel discussion.)

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WEDNESDAY PM, MAY 18 SATELLITE-WEST ROOM

Session WP2: 2:00–5:00 PM

Traffic And Transportation Planning

Chairman: D. G. MALCOLM
Management Technology Inc., Los Angeles, California.

WP2.1 ***California Integrated Transportation Study,** W. H. BENDER, *North American Aviation Inc., Los Angeles, California, and* C. J. POUNDERS, *University of Southern California, Los Angeles, California.*

WP2.2 ***Transportation Research to Support the Government's New Planning-Programming-Budgeting System,** CHARLES J. ZWICK, *Assistant Director, Bureau of the Budget, Washington, D.C.*

WP2.3 ***Program Design for Integrated Transportation Planning and Development,** ROBERT BICKNELL, *Management Technology Inc., Washington, D.C., and* D. G. MALCOLM, *Management Technology Inc., Los Angeles, California 90045.*

WP2.4 ***The Development and Validation of a Digital Simulation Model for Design of Freeway Diamond Interchanges,** A. V. GAFARIAN, E. HAYES, *and* W. W. MOSHER, JR., *System Development Corporation, Santa Monica, California.*

WEDNESDAY PM, MAY 18 SATELLITE-CENTER ROOM

Session WP3: 2:00–5:00 PM

Research And Development In Management Operations

Chairman: DAVID B. HERTZ
McKinsey and Company, Inc., 270 Park Avenue, New York, New York.

WP3.1 ***Management Implications of Time-Shared Computing,** GEORGE FEENEY, *General Electric Company, 570 Lexington Ave., New York, New York.*

WP3.2 ***Some Experimental Findings in Executive Decision Making Under Uncertainty,** PAUL E GREEN, *University of Pennsylvania, Philadelphia, Pennsylvania.*

WP3.3 ***Managers are Human: Research on the Management Process,** MICHAEL I. HALBERT, *Marketing Science Institute, Philadelphia 4, Pennsylvania*

WP3.4 ***Financial Control of Research and Development,** EDGAR A. PESSEMIER, *Purdue University, Lafayette, Indiana.*

WP3.5 ***Decision Critical Path Method: A Method for Simultaneous Planning, Scheduling, and Control of Projects,** GERALD L. THOMPSON, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania, and* WALLACE CROWSTON, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

WEDNESDAY PM, MAY 18 AVIATION-EAST ROOM

Session WP4: 2:00–5:00 PM

Flight Operations Planning For Manned Spaceflights

Chairman: MICHAEL W. LODATO
The MITRE Corporation, Bedford, Massachusetts.

WP4.1 ***The Use of a Computer Aid in Manned Space Station Experimental and Operational Planning,** R. E. MINK, *IBM Federal Systems Division, Space Guidance West, 9045 Lincoln Boulevard, Los Angeles, California.*

WP4.2 ***A Mission Scheduling System for Manned Space Flight,** R. F. KLAWA, *General Dynamics/Convair, San Diego, California.*

WP4.3 ***Closing the Planning-Scheduling-Allocation Loop,** FRANK B. KAPPER, *The MITRE Corporation, Bedford, Massachusetts.*

WP4.4 *PANEL, with members:*
LEO C. DRISCOLL, *The MITRE Corporation, Bedford, Massachusetts.*
F. D. SELBIE, JR., *The Martin Company, Denver, Colorado.*
NEAL M. BURNS, *Honeywell, Incorporated, Minneapolis, Minnesota.*

(Abstract WP4.4 contains an outline of the subject matter for this panel discussion.)

WEDNESDAY PM, MAY 18 AVIATION-WEST ROOM

Session WP5: 2:00–5:00 PM

Statistical Applications

Chairman: HERBERT SOLOMON
Statistics Department, Stanford University, Stanford, California.

WP5.1 ***Optimal Stopping,** MORRIS H. DEGROOT, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

WP5.2 ***Estimation of Parameters in Reliability Models,** BENJAMIN EPSTEIN, *Consultant, 768 Garland Drive, Palo Alto, California.*

WP5.3 ***Gambling for Survival,** ALAN TRUELOVE, *C-E-I-R, Inc., Beverly Hills, California.*

WP5.4 ***Optimum Sequential Procedures for Calibrating Complex Engineering Systems,** STEVE WEBB, *Rocketdyne, Canoga Park, California.*

WP5.5 ***Statistical Analysis of Scientific and Technical Information Needs,** ARNOLD GOODMAN, *Space and Information Systems Division, North American Aviation, Downey, California.*

WEDNESDAY PM, MAY 18 CALIFORNIA ROOM

Session WP6: 2:00–5:00 PM

Cost-Effectiveness Section I: Aerospace Applications

Chairman: JAY T. WAKELEY
Defense Research Corporation, Santa Barbara, California.

WP6.1 ***Surge Capability of an Air Logistic System,** ALFRED G. ASWAD, *Douglas Aircraft Company, Long Beach, California.*

WP6.2 ***Selection of Subsystems, Equipment and Performance for Optimum Weapon System Configuration,** JACK REBMAN, *Lockheed-California Company, Van Nuys, California.*

WP6.3 ***Cost Effectiveness Fallacies and Misconceptions Revisited,** A. D. KAZANOWSKI, *North American Aviation, Downey, California.*

WP6.4 ***On Criteria and a Selection Process,** W. A. DWYER, *The Boeing Company, Seattle, Washington.*

WP6.5 **Cost-Effectiveness of Current vs. Future Aircraft Runway Performance,** KARL SEILER, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

WP6.6 **Some Issues In Conducting Military Cost-Effectiveness Studies,** PETER D. FOX *and* DAN G. HANEY, *Stanford Research Institute, Menlo Park, California.*

WEDNESDAY PM, MAY 18 JUPITER-VENUS ROOM

Session WP7: 2:00–5:00 PM

Health, Welfare And Socio-Economic Developments

Chairman: JAMES L. TAYLOR
Northrop Corporation, Northrop Building, Beverly Hills, California.

WP7.1 *****Operations Analysis of American Education at the U.S. Office of Education,** ALEXANDER M. MOOD, *Office of Education, Department of Health, Education, and Welfare, Washington, D.C.*

WP7.2 **Computer Evaluation of the Diagnostic Decision Process in Disability Determination,** SYLVAN HACK *and* SAUL D. HEARN, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.*

WP7.3 **Hospital Patient Through-Put Analysis,** MIKE KOTTLER, *3592 Severn, Cleveland Heights, Ohio, and* HAROLD NISSLEY, *2925 Euclid, Cleveland, Ohio.*

WP7.4 **Implementation—An Application of the Literature to a Study of Decision Making in a Public Health Agency,** DAVID H. STIMSON, *University of California, Berkeley, California.*

WP7.5 **Programming a Plan for a Job Corps Training Center,** HARRY A. GRACE, *University of Southern California, Los Angeles, California.*

WP7.6 **War Gaming the War on Poverty,** THOMAS A. GOLDMAN, *Philco Corporation, 515 Pennsylvania Ave., Fort Washington, Pennsylvania.*

WP7.7 **The Use of Mathematical Programming in Water Quality Management,** ROLF A. DEININGER, *University of Michigan, Ann Arbor, Michigan.*

WP7.8 **Management Development and Productivity in Underdeveloped Nations,** HAROLD W. MARTIN, *Rensselaer Polytechnic Institute, Troy, New York.*

WP7.9 **Simulation of Shelter Systems in a Contaminated Environment,** JACK C. ROGERS, *Booz, Allen Applied Research, Inc., Los Angeles, California 90045.*

WP7.10 **Operations Research Models and Computer Applications in Food Service Management,** JOSEPH L. BALINTY, *Tulane University, New Orleans, Louisiana.*

WEDNESDAY PM, MAY 18 SATELLITE-EAST ROOM

5:00–5:30 PM

Military Applications Section: Business Meeting

Chairman: WALTER L. DEEMER
Section Chairman

WEDNESDAY PM, MAY 18 SATELLITE ROOM AREA

6:00–7:30 PM

No-Host Mixer

THURSDAY AM, MAY 19 SATELLITE-EAST ROOM

Session TA1: 9:00–11:30 AM

Transportation Science Section II: Airline Applications

Chairman: ALEC M. LEE
Air Canada, Montreal 2, Canada.

TA1.1 ***A Common Approach to Aircraft and Aircrew Scheduling,** J. TAYLOR, *B.O.A.C., Pennine, Terry's Lane, Cookham, Maidenhead, Berks., England.*

TA1.2 ***Understanding About OR: A Need for Decision-Making,** C. DEETMAN, *KLM Royal Dutch Airlines, Schlipol Airport, Amsterdam, SPLI/BG, The Netherlands.*

TA1.3 ***Commercial Airplane Market Analysis by Airline Simulation,** LEE R. HOWARD, *Lockheed-California Company, Burbank, California.*

THURSDAY AM, MAY 19 SATELLITE-WEST ROOM

Session TA2: 9:00–11:30 AM

Cost-Effectiveness Section II: Applications To Non-Military Government Problems, Part 1

Chairman: ALFRED BLUMSTEIN
Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.

TA2.1 ***Bureau of the Budget Objectives and Plans in Cost-Effectiveness Analysis,** HENRY ROWEN, *Assistant Director, Bureau of the Budget, Washington 25, D.C.*

TA2.2 ***Cost-Effectiveness Analysis at the State Level,** LESLIE E. CARBERT, *State Planning Officer, 11th and L Building, Sacramento, California.*

TA2.3 ***Cost-Effectiveness of Controlling Land Inputs,** HOWARD HJORT (AND STAFF), *Office of the Secretary, U.S. Department of Agriculture, Washington 25, D.C.*

TA2.4 ***Systems Analysis in the War on Poverty,** ROBERT A. LEVINE, *Office of Economic Opportunity, Washington 25, D.C.*

THURSDAY AM, MAY 19 SATELLITE-CENTER ROOM

Session TA3: 9:00–11:30 AM

Operations Research In The Medical Field

Chairman: RICHARD BELLMAN
University of Southern California, Los Angeles, California.

TA3.1 ***Problems of Large Hospital Administration,** VERNON L. NICKEL, *Rancho Los Amigos Hospital, 7601 East Imperial Highway, Downey, California.*

DISCUSSANT: CALVIN DAVIS, *Northrop NORAIR, Hawthorne, California.*

TA3.2 ***Simulation of a Psychiatric Out-patient Clinic,** COLIN SHANKS, *Department of Electrical Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.*

DISCUSSANT: ALAN J. ROWE, *Graduate School of Business, University of Southern California, Los Angeles, California.*

TA3.3 ***Simulation of the Initial Psychiatric Interview,** LARRY BRODY, *Los Angeles County General Hospital, 1200 North State Street, Los Angeles, California.*

DISCUSSANT: JOHN STARKWEATHER, *University of California, Medical Center, San Francisco, California.*

THURSDAY AM, MAY 19 AVIATION-EAST ROOM

Session TA4: 9:00–11:30 AM

Planning Applications

Chairman: KENNETH W. YARNOLD
System Development Corporation, Santa Monica, California.

TA4.1 ***OR Applied to Advertising in Depth,** RUSSELL L. ACKOFF, *University of Pennsylvania, Philadelphia, Pennsylvania.*

TA4.2 ***Simulation of a U.S. Navy Public Works Organization,** JOHN D. TOELLNER *and* JOHN B. HOWENSTINE, *Ernst & Ernst, 615 South Flower St., Los Angeles, California.*

TA4.3 ***Operational Research in Educational Planning: An Experimental Project by the O.E.C.D.,** *authored by The Educational Investment and Development Division, Organisation for Economic Co-Operation and Development, 2, rue Andre-Pascal, Paris 16^e, France.*

THURSDAY AM, MAY 19 AVIATION-WEST ROOM

Session TA5: 9:00–11:30 AM

Military Applications Section III: Logistics

Chairman: WALTER L. DEEMER
U.S. Arms Control and Disarmament Agency, Washington 25, D.C.

TA5.1 ***An Integrated Approach to Logistics Analysis,** C. B. MOORE, *Fort Worth Division of General Dynamics, Fort Worth, Texas.*

TA5.2 **An Application of Linear Programming to Strategic Deployment Problems,** GEORGE R FITZPATRICK *and* JUSTIN C. WHITON, *Research Analysis Corporation, McLean, Virginia.*

TA5.3 **Impact of Air Mobile Operations on Logistics Concepts: A Preliminary Look,** RAY M. CLARKE, *Research Analysis Corporation, McLean, Virginia.*

TA5.4 **Computer-Assisted Testing and Analysis of Logistics,** THOMAS B. ROELOGS, *Research Analysis Corporation, McLean, Virginia.*

TA5.5 **Decision Theoretic Analysis of Headquarters Logistical Command and Control Systems,** S. P. TODD, JR., *Dunlap and Associates, Inc., 1050 31st St., N.W., Washington, D.C.*

TA5.6 **A Computerized System for Forecasting Wartime Replacement Requirements,** MARTIN W. BROSSMAN, JOEL MORRIS, *and* VINCENT SARDELLA, *Research Analysis Corporation, McLean, Virginia.*

TA5.7 **A Method for Evaluating the Relative Effectiveness of the Field Army Medical Support System,** J. H. LANGSTON *and* B. B. LIND, *Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland.*

THURSDAY AM, MAY 19 CALIFORNIA ROOM

Session TA6: 9:00–11:30 AM

Optimization And Analysis

Chairman: CORLIN O. BEUM, JR.
Space and Information Systems, North American Aviation, Downey, California.

TA6.1 ***A Typical Operations Research Analysis Cycle and Its Iteration,** MARY A. STAADT, *The Boeing Company, Wichita, Kansas.*

TA6.2 **Optimization of Bank Portfolios: A Linear Programming Model,** WILLIAM F. BEAZER, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

TA6.3 **An Approach to a Technique for Designing an Organization,** E. J. MERRICK, *General Electric Company, Missile and Space Division, P.O. Box 8555, Philadelphia 1, Pennsylvania.*

TA6.4 **An Operations Research Approach to Economic Planning in Underdeveloped Nations,** R. L. GROVER *and* R. A. WILSON, *Northrop Norair, Hawthorne, California.*

TA6.5 **A Computer Program for More Flexible Inputs to Spatial Diffusion Process Simulations,** FORREST R. PITTS, *Social Science Research Institute. University of Hawaii, Honolulu, Hawaii.*

TA6.6 **Automated Production and Assembly of Modular Simulation Programs,** JOHN R. METZNER *and* BRUCE H. BARNES, *Penn State University, University Park, Pennsylvania.*

TA6.7 **Precision: A Scientific Vice?,** G. H. PERRY, *System Development Corporation, Santa Monica, California.*

TA6.8 **Cost Effectiveness and Utility Functions for Incentive Structures,** LIONEL L. FRAY, *W. G. Briggs and J. R. Russell, Harbridge House, Inc., 11 Arlington Street, Boston, Massachusetts.*

THURSDAY AM, MAY 19 JUPITER-VENUS ROOM

Session TA7: 9:00–11:30 AM

Inventory Control And Statistics

Chairman: MICHAEL J. ERDEI
Operations Analysis and Research, Hughes Aircraft Co., Los Angeles, California.

TA7.1 **Sensitivity of Decisions to Probability Estimation Errors: A Reexamination,** PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia,* ALLAN H. MURPHY, *University of Michigan, Ann Arbor, Michigan and* HERBERT H. ISAACS, *System Development Corporation, Santa Monica, California.*

TA7.2 **Heuristic Programming Applied to Inventory Problems,** KEVIN R. JONES, *The University of Kansas, Lawrence, Kansas.*

TA7.3 **Retail IMPACT (Inventory Management Program And Control Techniques) System,** M. D. SEVERSKY, *IBM Data Processing Division, 2651 Strang Boulevard, Yorktown Heights, New York.*

TA7.4 **Errors in Adaptive Forecasting Formulas,** J. L. BRENNER *and* D. A. D'ESOPO, *Stanford Research Institute, Menlo Park, California.*

TA7.5 **A Conditional Binomial Assay Model for Advertising Sales Effectiveness,** WILLIAM J. WROBLESKI, *The University of Michigan, Ann Arbor, Michigan.*

TA7.6 **Statistical Techniques Applied to Testing of Explosive Devices,** R. R. BOYCE, *and* J. E. SCHONBLOM, *Martin Company, Orlando, Florida.*

TA7.7 **Concept Mapping: Creation of Indices with Specified Estimating Properties,** R. D. JONES, *University of Missouri, Kansas City, Missouri.*

TA7.8 **Poker—A Time-Series Analysis of 350 Games,** M. H. GARNHOLZ, *TRW System Group of TRW Inc., One Space Park, Redondo Beach, California.*

TA7.9 **A Behavioral Model of the Prisoner's Dilemma,** J. R. EMSHOFF, R. W. BLANNING, *and* A. G. RAO, *University of Pennsylvania, Department of Operations Research and Statistics, Philadelphia, Pennsylvania.*

THURSDAY AM, MAY 19 SATELLITE-EAST ROOM

11:30 AM–Noon

Operations Research Society Of America Annual Business Meeting

Chairman: GEORGE SHORTLEY
President, Operations Research Society of America

THURSDAY PM, MAY 19 SATELLITE-EAST ROOM

Session TP1: 2:00–5:00 PM

Transportation Science Section III: General Applications

Chairman: ALEC M. LEE
Air Canada, Montreal 2, Canada.

TP1.1 ***A Study in Wave Theories of Traffic Flow,** C. K. WOJCIK *and* L. A. PIPES, *University of California, Los Angeles 24, California.*

TP1.2 ***Ship Scheduling in the Kiel Canal and Statistical Aspects of Optimization Techniques,** H. MERTIN, *IBM Germany, Berlin, Germany.*

TP1.3 ***Truck Driver Scheduling,** A. BOMBERAULT, C. LEMKE, *and* E. WRATHALL, *IBM Data Processing Division, White Plains, New York.*

TP1.4 ***Parametric Relations in Transit Route Structure Models,** ERNEST B. COHEN *and* SOLOMON MOLDOFF, *General Electric Co., King of Prussia, Pennsylvania.*

TP1.5 ***Continuum Assignment of Traffic on a Circular City,** TENNY LAM *and* G. F. NEWELL, *Institute of Transportation and Traffic Engineering, University of California, Berkeley, California.*

THURSDAY PM, MAY 19 SATELLITE-WEST ROOM

Session TP2: 2:00–5:00 PM

Cost-Effectiveness Section III: Applications To Non-Military Government Problems, Part 2

Chairman: ALFRED BLUMSTEIN
Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.

TP2.1 ***Public Works Projects,** BENJAMIN CHINITZ, *Economic Development Administration, Washington 25, D.C.*

TP2.2 ***Program Budgeting for Natural Resources and Education,** WERNER Z. HIRSCH, *University of California, Los Angeles, California.*

TP2.3 ***Effective Resource Allocation in Universities,** HARRY WILLIAMS, *Institute for Defense Analysis, 400 Army-Navy Drive, Arlington, Virginia.*

TP2.4 ***Cost-Effectiveness Analysis in the Administration of Justice,** JULIUS MARGOLIS, *Department of Economics, Stanford University, Stanford, California.*

TP2.5 ***System Analysis of the Los Angeles Police Department Crime Information System,** HERBERT H. ISAACS, *System Development Corporation, Santa Monica, California.*

THURSDAY PM, MAY 19 SATELLITE-CENTER ROOM

Session TP3: 2:00–5:00 PM

Logistics

Chairman: JAMES W. PETERSON
The RAND Corporation, Santa Monica, California.

TP3.1 ***Operations Research and Applied Logistics,** COLONEL EUGENE C. PARKERSON, *Hill Air Force Base, Ogden, Utah.*

TP3.2 ***A Systems Approach to Base Stockage: Its Development and Test,** H. C. CAMPBELL, *The RAND Corporation, Santa Monica, California, and* T. L. JONES, *Ent Air Force Base, Colorado.*

TP3.3 ***A Model for the Design and Evaluation of Air Cargo Systems,** ROBERT B. FETTER, *Yale University, New Haven, Connecticut, and* RONALD C. STEORTS, *Research Triangle Institute, P.O. Box 490, Durham, North Carolina.*

TP3.4 ***On-Line Control of Maintenance Activities,** STEPHEN M. DREZNER *and* RICHARD L. VAN HORN, *The RAND Corporation, Santa Monica, California.*

THURSDAY PM, MAY 19 AVIATION-EAST ROOM

Session TP4: 2:00–5:00 PM

Modeling, Simulation And Computer Languages

Chairman: DANIEL TEICHROEW
Case Institute of Technology, Cleveland 6, Ohio.

TP4.1 ***Highlights of a Dynamic System Description Language,** H. S KRASNOW, *Advanced Systems Development Division, IBM Corporation, 2651 Strang Boulevard, Yorktown Heights, New York.*

TP4.2 ***Incremental Simulation,** M. GREENBERGER, *Center for Research in Management Science, University of California, Berkeley, California.*

TP4.3 ***Generalized Models of Information Processing Systems,** G. K. HUTCHINSON, *Lockheed Missiles & Space Company, Sunnyvale, California.*

TP4.4 ***SimOptimization Techniques: Iteration Two,** E. L. LUTHER *and* H. N. MARKOWITZ, *California Analysis Center, Inc., 225 Santa Monica Boulevard, Santa Monica, California.*

THURSDAY PM, MAY 19 AVIATION-WEST ROOM

Session TP5: 2:00–5:00 PM

Operations Research And The Behavioral Sciences

Chairman: JOHN V. ZUCKERMAN
Graduate School of Business Administration, University of Southern California, Los Angeles, California.

TP5.1 ***Two Types of Task Teamwork,** L. S. CHRISTIE, *System Development Corporation, Santa Monica, California.*

TP5.2 ***A General System Model for Investigating Feedback Signal Paths to the Secondary/Vocational-Technical School,** LEONARD C. SILVERN, *Education and Training Consultants, 979 Teakwood Road, Los Angeles, California.*

TP5.3 ***Operations Research and Cost-Benefit Models for Innovation in U.S. Public School Systems,** NORTON F. KRISTY, *Astrodata-Simutech Inc., Los Angeles, California 90024.*

TP5.4 ***Implementation of Operations Research Results: Contributions from the Behavioral Sciences,** JOHN V. ZUCKERMAN, *University of Southern California, Los Angeles, California.*

THURSDAY PM, MAY 19 CALIFORNIA ROOM

Session TP6: 2:00–5:00 PM

Uses Of Operations Research In Banking

Chairman: HARRY GROSSMAN
Security First National Bank, 561 S. Spring St., Los Angeles, California.

TP6.1 ***A Two-Stage Forecasting Model: Exponential Smoothing and Multiple Regression,** DWIGHT B. CRANE *and* JAMES R. CROTTY, *Mellon National Bank and Trust Company, Mellon Square, Pittsburgh, Pennsylvania.*

TP6.2 ***Optimal Level Debt Schedules for Municipal Bonds,** Kalman J. Cohen, *Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pennsylvania, and* Frederick S. Hammer, *Bankers Trust Company, New York, New York.*

TP6.3 ***Application of Credit Scoring in a Bank,** G. Randolph Jenks, *Security First National Bank, 561 South Spring Street, Los Angeles, California.*

THURSDAY PM, MAY 19 Jupiter-Venus Room

Session TP7: 2:00–5:00 PM

Military Applications Section IV: Tactics

Chairman: Carroll L. Zimmerman
Aerospace Sciences, Douglas Aircraft Co., Long Beach, California.

TP7.1 ***Some Further Results in the Theory of Stochastic Duels,** C. J. Ancker, Jr., *System Development Corporation, Santa Monica, California.*

TP7.2 **Solution of the Extended Lanchester Equations of Warfare Used in the TWSP,** Fred K. Dashiell *and* William W. Fain, *Aerospace Sciences, Douglas Aircraft Co., Long Beach, California.*

TP7.3 **A Computerized Quick Game for Deployment Analyses,** Richard E. Zimmerman, Dudley Edwards, Edward P. Kerlin, Donald Mader, *and* James D. Pomeroy, *Research Analysis Corporation, McLean, Virginia.*

TP7.4 **Application of Dynamic Programming to the Problem of Firing Missiles at Targets Whose Values Change With Time,** Alan Washburn, *The Boeing Company, Seattle, Washington.*

TP7.5 **Measures of Effectiveness for Anti-Aircraft, Guided Missile Systems,** Edward M. Hadro, *Raytheon Company, Bedford, Massachusetts.*

TP7.6 **A Basic Operations Research Approach to the Determination of Rifle Operational Hit Probability,** H. C. Alberts, *Stanford Research Institute, P.O. Box 316, Fort Ord, California.*

TP7.7 **Redetecting an Inexactly Located Submarine,** F. R. S. Dressler, *Bell Helicopter Company, P.O. Box 482, Fort Worth, Texas.*

TP7.8 **Cost-Performance Analysis of an IR Mapping System,** Eugene C. Mikelonis, *HRB-Singer, Inc., Box 60, State College, Pennsylvania.*

TP7.9 **Methodology for Estimating Casualties from Fallout Attacks,** Floyd I. John, *Stanford Research Institute, Menlo Park, California.*

THURSDAY PM, MAY 19 Satellite-East Room

5:00–5:30 PM

Transportation Science Section: Business Meeting

Chairman: Denos C. Gazis
Section Chairman

THURSDAY PM, MAY 19 Satellite Room Area

6:00–7:30 PM

Cocktail Party

THURSDAY PM, MAY 19 Satellite Room

Session TPB: 7:30–9:00 PM

BANQUET: Retiring Presidential Address

Chairman: George E. Kimball
Arthur D. Little, Inc., Cambridge, Massachusetts.

SPEAKER: George Shortley, *President of Operations Research Society of America for 1965–1966, Booz, Allen Applied Research, Inc., Bethesda, Maryland.*

FRIDAY AM, MAY 20 Satellite-East Room

Session FA1: 9:00–11:45 AM

Panel On: Computers And Operations Research

Chairman: H. R. J. Grosch
General Electric Co., TEMPO, Santa Barbara, California.

PANEL MEMBERS:

A. S. Douglas, *C-E-I-R (U.K.) Ltd., 84 Kingsway, London, W.C.2, England.*

Joseph J. Magnino, Jr., *IBM Technical Information Retrieval Center, Thomas J. Watson Research Center, Yorktown Heights, New York.*

Hugh V. O'Neill, *Spacecraft Department, General Electric Co., 4901 Fairmont Avenue, Bethesda, Maryland.*

(Abstract FA1 contains an outline of the subject matter for this panel discussion.)

FRIDAY AM, MAY 20 SATELLITE-WEST ROOM

Session FA2: 9:00 AM–Noon

(Cosponsored by Cost-Effectiveness and Military Applications Sections)

Panel On: Measuring The Effectiveness Of Our Military And Political Effort In Viet Nam

Chairman: LEONARD UNGER

Deputy Assistant Secretary of State for Far Eastern Affairs, (Former Ambassador to Laos), Washington 25, D.C.

PANEL MEMBERS:

MAJOR GENERAL WILLIAM R. PEERS, *Special Assistant for Counterinsurgency and Special Activities, Joint Chiefs of Staff, Washington 25, D.C.*

SEYMOUR J. DEITCHMAN, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

STEPHEN T. HOSMER, *The RAND Corporation, Santa Monica, California.*

(Abstract FA2 contains an outline of the subject matter for this panel discussion.)

FRIDAY AM, MAY 20 SATELLITE-CENTER ROOM

Session FA3: 9:00 AM–Noon

Cost-Effectiveness Section IV: Transportation Applications, Part 1

(Cosponsored by Transportation Science Section)

Chairman: MARTIN WOHL

National Science Foundation Faculty Fellow, Univ. of Calif., Berkeley, California.

FA3.1 ***The Role of Transport in Developing Countries: A Development Planning Model,** PAUL O. ROBERTS, JR., *Harvard University, Cambridge, Massachusetts.*

DISCUSSANT: CHARLES ZWICK, *Assistant Director, Bureau of the Budget, Washington 25, D.C.*

FA3.2 ***Evaluation Procedures for Regional Transportation Planning: The Northeast Corridor Transportation Project,** H. W. BRUCK *and* ROBERT T. CROW, *U. S. Department of Commerce, Washington 25, D.C.*

DISCUSSANT· GERALD KRAFT, *Charles River Associates, Cambridge, Massachusetts.*

FRIDAY AM, MAY 20 AVIATION-EAST ROOM

Session FA4: 9:00 AM–Noon

Development Assistance: A Challenge For Analysis

Chairman: JOHN D. WILKES
Agency for International Development, Dept. of State, Washington, D.C.

FA4.1 ***Applying Analytic Methods to Problems of Development Assistance,** JAMES FARMER, *San Fernando Valley State College, Northridge, California.*

FA4.2 ***Analysis of the Human Interface in Development Project Feasibility Studies,** ARNOLD KENT, *Northrop Corporation, 9744 Wilshire Boulevard, Beverly Hills, California, and* JOHANNES WILBERT, *University of California, Los Angeles, California.*

FA4.3 ***Systems Analysis for Planning Infrastructure Growth in the Developing Nations,** JAMES A. RAFFERTY, *Lockheed International, Los Angeles, California.*

FRIDAY AM, MAY 20 AVIATION-WEST ROOM

Session FA5: 9:00 AM–Noon

Linear Programming Results

Chairman: A. CHARNES
Technological Institute, Northwestern University, Evanston, Illinois.

FA5.1 ***A Mixed Integer Problem,** C. E. LEMKE, *Rennselaer Polytechnic Institute, IBM Systems Research Fellow, 590 Madison Avenue, New York, New York.*

FA5.2 ***Systems of Differentiable Inequalities,** MORTON SLATER, *SANDIA Corporation, Albuquerque, New Mexico.*

FA5.3 ***Semi-Infinite Programming, Differentiability and Geometric Programming,** A. CHARNES, *Northwestern University, Evanston, Illinois,* W. W. COOPER, *Carnegie Institite of Technology, Pittsburgh, Pennsylvania, and* K. O. KORTANEK, *Cornell University, Ithaca, New York.*

FRIDAY AM, MAY 20 CALIFORNIA ROOM

Session FA6: 9:00 AM–Noon

Panel On: The Operational Relevance Of Mathematical Programming Models For Financial Planning And Capital Budgeting

Chairman: KALMAN J. COHEN
Graduate School of Industrial Administration, Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

PANEL MEMBERS:

FREDERICK S. HAMMER, *Bankers Trust Company, New York, New York.*

FREDERICK S. HILLIER, *Department of Industrial Engineering, Stanford University, Stanford, California.*

JOSEPH F. McCLOSKY, *Security First National Bank, 561 S. Spring, Los Angeles, California.*

LOWELL K. STROHL, *Esso Research and Engineering Company, Madison, New Jersey.*

H. MARTIN WEINGARTNER, *Alfred P. Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

(Abstract FA6 contains an outline of the subject matter for this panel discussion.)

FRIDAY AM, MAY 20 JUPITER-VENUS ROOM

Session FA7: 9:00 AM–Noon

Missile And Space Applications

Chairman: GEORGE W. MORGENTHALER
Martin Company, Denver, Colorado.

FA7.1 **Long Range Satellite Systems Improvements,** N. T. GRISSMORE, *The George Washington University, Washington, D.C., and* V. SELMAN, *System Sciences Corp., Falls Church, Virginia.*

FA7.2 **A Method of Ordering and Selecting Lunar Experiments According to Scientific Merit,** E. M. BARTEE, *University of Alabama in Huntsville, Huntsville, Alabama.*

FA7.3 **A Space Mission Success Evaluation Model,** ROBERT G. CHAMBERLAIN, *Jet Propulsion Laboratory, Pasadena, California.*

FA7.4 **Concepts of Investment Return in Space Program Evaluation and Comparison,** J. G. Srygley, *Fort Worth Division of General Dynamics, Fort Worth, Texas.*

FA7.5 **The Evaluation of Space System Operational Effectiveness,** W. Thomas Weir *and* John S. Youtcheff, *General Electric Company, Missile and Space Division, Philadelphia, Pennsylvania.*

FA7.6 **Optimal Location of Tracking Stations,** Dennis M. Galvin, *North American Aviation, Downey, California.*

FA7.7 **Effectiveness of Maintainable Space Systems,** Glen Benz, *Daniel, Mann & Mendenhall, 3325 Wilshire Blvd., Los Angeles, California.*

FA7.8 **An Effectiveness Model for Satellite Threat Systems,** H. C. Sebring, *General Electric Company, Valley Forge Space Technology Center, Philadelphia 1, Pennsylvania.*

FA7.9 **The MINUTEMAN Weapon System Effectiveness Model,** Jon R. Aderhold, *TRW Systems, 600 E. Mill Street, San Bernardino, California.*

FA7.10 **Computer Models for Missile Range Scheduling,** William C. Suhler, *Federal Systems Center, IBM, 7220 Wisconsin Ave., Bethesda, Maryland.*

FA7.11 **Kill Probabilities for Missiles with Multiple Warheads,** Alan R. Washburn *and* Norman E. Schille, *The Boeing Company, Seattle, Washington.*

FRIDAY PM, MAY 20 SATELLITE-EAST ROOM

Session FPL: 12:15–1:45 PM

Luncheon

Chairman: Paul Brock
General Electric Company, TEMPO, Santa Barbara, California.

SPEAKER: Dr. Herman H. Goldstine, *Director of Scientific Development, IBM, White Plains, New York.*

SUBJECT: **The Computer in Operations Research**

FRIDAY PM, MAY 20 SATELLITE-EAST ROOM

Session FP1: 2:15–5:00 PM

Cost-Effectiveness Section V: Can Cost-Effectiveness Of Military R&D Be Measured?

(*Cosponsored by Military Applications Section*)

Chairman: ROBERT L. PERRY
Economics Dept., The RAND Corporation, Santa Monica, California.

FP1.1 ***Introduction: The Mythography of Military R&D,** ROBERT L. PERRY, *The RAND Corporation, Santa Monica, California.*

FP1.2 ***A Critique of Cost-Effectiveness Applications to Decision-Making in Defense,** KLAUS KNORR, *Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, New Jersey.*

FP1.3 ***Methodological Problems in Evaluating the Effectiveness of Military Aircraft Development,** THOMAS K. GLENNAN, JR., *The RAND Corporation, Santa Monica, California.*

FP1.4 ***Problem Mongers, Solution Mongers, and Weapon Systems,** PAUL J. STURM, *Office of the Director of Defense Research and Engineering, Department of Defense, Washington 25, D.C.*

FRIDAY PM, MAY 20 SATELLITE-WEST ROOM

Session FP2: 2:00–5:00 PM

Cost-Effectiveness Section VI: Transportation Applications, Part 2

(*Cosponsored by Transportation Science Section*)
Chairman: MARTIN WOHL

National Science Foundation Faculty Fellow, University of California, Berkeley, California.

FP2.1 ***Cost-Effectiveness Criteria for Evaluating Transportation Alternatives,** ALLEN V. BUTTERWORTH, *General Motors Defense Research Laboratories, Santa Barbara, California.*

DISCUSSANT: ALLEN R. FERGUSON, *Systems Economics Division, Planning Research Corporation, 1875 Connecticut Ave., N.W., Washington, D.C.*

FP2.2 ***Optimization and Pricing of Traffic and Facilities,** WILLIAM VICKREY, *Columbia University, New York 27, New York.*

DISCUSSANT: JOHN R. MEYER, *Harvard University, Cambridge, Massachusetts.*

FRIDAY PM, MAY 20 SATELLITE-CENTER ROOM

Session FP3: 2:00–5:00 PM

Analytical Techniques

Chairman: MILTON ASH
E. H. Plesset Associates, 2444 Wilshire Blvd., Santa Monica, California.

FP3.1 ***A Finite Renewal Algorithm for the Knapsack and Turnpike Models,** JEREMY F. SHAPIRO *and* HARVEY M. WAGNER, *Stanford University, Stanford, California.*

FP3.2 ***Invariant Forecasters for Some Weibull Distributions,** J. TIAGO *de* OLIVEIRA, *University of Lisbon, Lisbon, Portugal, and* S. B. LITTAUER, *Columbia University, New York, New York.*

FP3.3 ***The Use of Estimating Formulas in O.R.,** GEORGES BRIGHAM, *Arthur Andersen & Co., 501 Norton Building, Seattle, Washington.*

FP3.4 ***Reliability and Confidence of Multicomponent Systems,** G. J. SCHICK, *University of Southern California, Los Angeles, California, and* R. J. PRIOR, *Douglas Aircraft Co., Santa Monica, California.*

FRIDAY PM, MAY 20 AVIATION-EAST ROOM

Session FP4: 2:00–5:00 PM

Military Applications Section V: General Developments

Chairman: C. J. ANCKER, JR.
System Development Corporation, Santa Monica, California.

FP4.1 ***Pay-Off Measures for the Allocation of Military Budgets,** R. H. BLYTHE, JR., *North American Air Defense Command, Ent Air Force Base, Colorado.*

FP4.2 **Military Requirements and Research Selection: Problems and Approaches,** H. D. LERNER, *Applied Psychology Corporation, Arlington, Virginia, and* E. STAVELEY, *Office of Naval Analysis, Washington 25, D.C.*

FP4.3 **Federal Support for Independent Research and Development,** S. W. HENDERSON, *System Sciences Corporation, Falls Church, Virginia.*

FP4.4 **Operations Research in Military Command and Control Systems,** RICHARD L. PLOSS, *Litton Industries, Beverly Hills, California.*

FP4.5 **A Graphical/Cost Approach to Some Weapon System Problems,** E. J. ALYANAK, *The Bendix Corporation, Mishawaka, Indiana.*

FP4.6 **Terrain Representation Techniques in Computerized Simulation,** RICHARD R. HODGES, *Logistic Studies Office, P O. Box 5175, Fort Lee, Virginia.*

FP4.7 **Types of Weapons Evaluation Studies Conducted by the Combat Operations Research Group (CORG) for the U.S. Army Combat Developments Command,** CARLTON COMBS, JR., *Combat Operations Research Group, Fort Belvoir, Virginia.*

FP4.8 **Technical, Organizational, and Communicational Dimensions of Work Requirements: Development of Job Design Profiles for Engineering Departments of Navy Destroyers,** MALCOLM J. CARR, *U.S. Naval Personnel Research Activity, San Diego, California.*

FP4.9 **Decision Theoretic Analysis of Requirements for Identification Information,** BERNARD H. STOWENS, *Dunlap and Associates, Inc., Darien, Connecticut.*

FP4.10 **New Developments Human Factors Program,** WILLIAM L. HOPKINS, *Bureau of Naval Personnel, Department of the Navy, Washington, D.C.*

FP4.11 **Site Security—Some Qualitative Considerations,** G. R. DESI, *Westinghouse Electric Corporation, Electronics Division, Baltimore 3, Maryland.*

FRIDAY PM, MAY 20 AVIATION-WEST ROOM

Session FP5: 2:00–5:00 PM

Gaming And Programming, II

Chairman: ARNO JAEGER

Graduate School Mathematics Dept., University of Cincinnati, Cincinnati, Ohio.

FP5.1 ***Solution Methods for Chance Constrained Programming,** GIFFORD, H. SYMONDS, *Box 222, Rocky Hill, New Jersey.*

FP5.2 **Primal Decomposition Methods for Structured Linear Programming Problems,** EDWIN V. W. ZSCHAU, *Stanford University, Stanford, California.*

FP5.3 **Change-Constrained Generalized Networks,** A. CHARNES, *Northwestern University,* M. KIRBY, *University of Chicago, Chicago 37, Illinois, and* W. RAIKE, *Northwestern University, Evanston, Illinois*

FP5.4 **A Simplified Decomposition Technique for Large Angular Linear Programs,** P. M. GHARE, *Texas Technological College, Lubbock, Texas.*

FP5.5 **Bivalent Nonlinear Programming,** PETRU L. IVANESCU *and* SERGIU RUDEANU, *Institute of Mathematics, Romanian Academy, 47 Eminescu Street, Bucharest, Romania.*

FP5.6 **Bivalent Hiperbolic Programming,** Petru L. Ivanescu, *Institute of Mathematics, Romanian Academy, 47, Eminescu Street, Bucharest, Romania.*

FP5.7 **Pivot Rules in Linear Programming,** Victor Klee, *University of Washington, Seattle, Washington.*

FP5.8 **On the Convex Hull of a Finite Set,** Christoph Witzgall, *National Bureau of Standards, Washington, D.C.*

FP5.9 *On Solving Bi-Criterion Mathematical Programs,* Arthur M. Geoffrion, *University of California, Los Angeles 24, California.*

FP5.10 **The Tank Assignment Problem,** Lawrence Briskin, *The Carborundum Company, P.O. Box 337, Niagara Falls, New York.*

FRIDAY PM, MAY 20 California Room

Session FP6: 2:00–5:00 PM

Papers On Planning And On Research And Development

Chairman: Howard Laitin
Hughes Aircraft Company, Culver City, California.

FP6.1 ***The Role of Operations Research in Corporate Long-Range Planning with Respect to Programs for R&D, Education and Career Development,** Thomas E. Oberbeck, *Office of Research Analyses (OAR) Holloman AFB, New Mexico.*

FP6.2 ***The Effects of Perceived Needs and Means on the Generation of Ideas for Industrial R and D Projects,** Norman R. Baker, *Purdue University Lafayette, Indiana,* A. H. Rubenstein, *and* Jack Siegman, *Northwestern University, Evanston, Illinois.*

FP6.3 **Reprogramming Analysis for R&D and Other Activities,** Mark Alfandary-Alexander, *U.S. Atomic Energy Commission, Washington 25, D.C.*

FP6.4 **Cost-Effectiveness in Research and Development: Observations on a Case Study,** Hans J. Laue, *Stanford Research Institute, Menlo Park. California.*

FP6.5 **Truncation and End-Effect Corrections for Long Range Planning Models,** W. P. Drews *and* L. A. Rapoport, *Esso Research and Enigneering Company, Florham Park, New Jersey.*

FP6.6 **The Optimization of an Already-Scheduled Packaging Program,** B. Gentry Lee, *Martin Company, Denver, Colorado.*

FP6.7 **Paraphysical Variables in Weapon System Analysis,** Irving Casey, *Analytic Services Inc., 5613 Leesburg Pike, Falls Church, Virginia.*

FP6.8 **A Minimum Risk Manpower Scheduling Technique,** Roger F. Jewett, *Lockheed-California Company, Burbank, California.*

FP6.9 **A Model of a Budgetary System's Ways of Influence,** Göran Widebäck, *University of Lund, Lund, Sweden, and Center for Research in Management Science, University of California, Berkeley, California.*

FRIDAY PM, MAY 20 Jupiter-Venus Room

Session FP7: 2:00–5:00 PM

Applied Automation

Chairman: Eugene A. Harris
General Electric, TEMPO, Santa Barbara, California.

FP7.1 ***Leviathan Research: Recent Findings and Next-Generation Models,** Beatrice *and* Sydney Rome, *System Development Corporation, Santa Monica, California.*

FP7.2 **Problems in Simulating Communications Networks,** Bernard Backhaut, *Transportation and Communications Service, General Services Administration, 18th and F Streets, N.W., Washington, D.C.*

FP7.3 **Optimum Forcing of a Telephone Company Business Office,** K. S. Usui *and* L. M. Schumann, *The Southern New England Telephone Company 300 George Street, New Haven, Connecticut.*

FP7.4 **A Heuristic Approach to Routing Telephone Traffic,** R. C. Carlson, *Bell Telephone Laboratories, Holmdel, New Jersey,* K. S. Usui *and* R. G. Maher, *The Southern New England Telephone Company, 300 George Street, New Haven, Connecticut.*

FP7.5 **The Feasibility of Automated Trust Administration,** William D. Griffin, *HRB-Singer, Inc., P.O. Box 60, State College, Pennsylvania.*

FP7.6 **Simulation Models in Marketing,** Harold Weitz, *IBM Corporation, 2651 Strang Blvd., Yorktown Heights, New York.*

FP7.7 **Concepts for Simulating Management Strategies as Applied to a Maintenance Parts Logistics Environment,** S. Fielden, *IBM Corporation, Box 390, Poughkeepsie, New York.*

FP7.8 **An Evaluation of the MILITRAN Programming Languages,** Kenneth Wigler, *Naval Command Systems Support Activity, Washington Navy Yard, Washington, D.C.*

FP7.9 **An Analyst's View of MILITRAN,** THOMAS GIAMMO, *Systems Research Group, Inc., 1501 Franklin Avenue, Mineola, New York.*

FP7.10 **An Information Retrieval System for a Small Operations Research Group,** PIERRE M. TULLIER *and* THOMAS W. MASON, *The Franklin Institute, 1401 Wilson Boulevard, Arlington, Virginia.*

FP7.11 **Computer Information Retrieval and R&E Management,** JOSEPE J. MAGNINO, JR., *IBM Corporation, P.O. Box 218, Yorktown Heights, New York.*

Abstracts

WA1 The U.S. Space Program—An Assessment and a Prognostication, (Panel). *Session chaired by* RAOUL J. FREEMAN, *General Electric Company, 570 Lexington Ave., New York, New York.*

The discussion will be devoted to a review of the current status of various aspects of our national space program and to a forecast of what the program will and/or should be in the future. Potential contributions for operations research may be highlighted. Members of the panel represent a broad spectrum of backgrounds and functions associated with the space program. The discussion should serve to provide a useful environmental setting for the operations researcher who will play an ever greater role in space sciences.

Open Discussion With more and more operations researchers becoming concerned with space sciences, it is of value to determine if there is sufficient interest to form a Space Sciences Section of ORSA. The usual benefits of closer interchange of information, organization of sessions and discussions devoted to this specific subject matter and formation of a central contact point for this type of work would result from the creation of a Space Sciences Section of ORSA.

WA2.1* Air Defense War-Game Model of the Japanese Air Defense Force, KAZUO IMAMURA, *Operations Analysis Group, Japanese Air Defense Force, Tokyo, Japan.*

This paper explains the air defense war-game model which was developed by the Japanese Air Defense Force in 1964 and is actually employed for establishment of our Defense Build-up Plan. This model was developed to evaluate the effectiveness of air defense operations against enemy bombers and also to assess resultant damage to the ground targets. The characteristics of this model are: 1. It is assumed that both sides have complete information. Consequently, in various air battle situations the combat is executed rationally without recourse to the commander's judgments and decisions. 2. This model is a Monte Carlo type. Also, time sequenced operations are selected to reflect the degradation of effectiveness of the air defense operations from the damages received over time. 3. This model was programmed by Fortran II. The computations were run by using UNIVAC 1107 and G-20.

WA2.2 Evaluation and Optimization of Tactical Aircraft Avionics—Statement of the Problem and Approach to the Solution, H. G. LUSTIG *and* P. SCHWARTZ, *Hughes Aircraft Company, Culver City, California.*

The current emphasis on conventional warfare in all levels from counter-guerilla operations through extended HE conflict has raised questions concerning both the kind and degree of avionics capability required in future tactical aircraft. Use of conventional high explosive weapons generally requires repeated sorties to attain high damage levels even with accurate delivery systems. Accordingly, exposure to enemy airborne and ground defenses is high. This requires provisions in the weapon system for maintaining satisfactory levels of penetration survivability. The study described in this paper is directed toward determining the preferred configuration for an advanced avionics subsystem in a tactical fighter-bomber. The evaluation and optimization problem should be stated in the framework of practically realizable military situations—nominal, optimistic, and pessimistic. For each of the military phases objectives can be stated in terms of required target damage or decreases in enemy force efficiency. Furthermore a specific time is allowable for the execution of each phase. The problem can then be stated as the determination of a single aircraft/avionic system type or mix of types such that the objectives of all phases can potentially be accomplished with the least peacetime force investment. The paper is concerned with stating the progress from hypothetical military-political situations to the quantification and analysis of each step required for avionic design evaluation and optimization. A total work flow diagram is developed and insight to special techniques of analysis is given as necessary to establish a complete analysis plan.

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* Invited paper.

WA2.3 Evaluation and Optimization of Tactical Aircraft Avionics—Air-to-Air Models, J. Pratt *and* F. Moloney, *Hughes Aircraft Company, Culver City, California.*

The paper is a discussion of five models developed at the Hughes Aircraft Company to estimate the effectiveness of manned interceptors and escorts against enemy aircraft. The models are designed to enable consideration of air defense, escort, self-defense, and air surveillance missions. For the air defense case the models have incorporated lead collision, lead pursuit and pursuit attacks. Sensors aboard the intercepting aircraft may be pulse radar, pulse-doppler radar, coherent moving target indicator radar and infrared. Complete interceptor-target kinematics are represented including ground vectoring and velocity errors as well as pilot effects on time to lock on. The models are Monte Carlo type allowing the determination of probability of detection, conversion and kill. A duel model has been developed for the case of two isolated non-passive targets in which both aircraft engage in firing at the other as possible. Aircraft movements are represented as dependencies based on target movement. Sensor detection and scan limits and armament range are represented in the engagement. Various maneuvers and firing tactics can be examined in detail in evaluation of complete aircraft/avionics capability. For the case of multiple duel engagements a computational algorithm has been developed to determine outcomes based on the isolated duel results. Qualitative results are presented and indications given of how the outcomes affect the total evaluation.

WA2.4 Evaluation and Optimization of Tactical Aircraft Avionics—Forward Looking Air-to-Ground (FLAG) Model, D. L. Lafferty, *Hughes Aircraft Company, Culver City, California.*

The FLAG model is a time increment sequenced program designed for simulation of the detection, recognition and weapon delivery phases of typical tactical reconnaissance/strike missions. The detection and recognition functions are particularized to forward-looking scanning sensor systems of arbitrary field of view and resolution. During each time increment the recognition cycle is executed. Recognition and detection are based on modifications of a formula derived by Dr. H. H. Bailey of the RAND Corporation, which involves display contrast, image angle subtended at the viewer, the number of resolution elements included in the target image, the portion of the total display area occupied by the image, and finally, the time available for detection or recognition. If detection and recognition occur, course correction and weapon delivery follow. The following statistical quantities are the analytical outcome of the FLAG model: 1) probability of detecting the target, 2) probability of recognizing the target, 3) probability of killing the target, 4) probability of recognition given detection, 5) probability of kill given recognition, 6) the maximum, average and one sigma deviation of the distance at which detection was made, 7) the maximum, average and one sigma deviation of the distance at which recognition was made, 8) the maximum, average and one sigma deviation of the distance at which the target was recognized and subsequently killed. The purpose of having such detailed outputs is that correlation with control field test data is desired. It is expected that with the suitable analytical framework now in hand that a better predictive capability can be obtained based on field experiments.

WA2.5 Evaluation and Optimization of Tactical Aircraft Avionics—Selection of Preferred Alternatives by the Use of Linear Programming and Coefficient Models, R. M. McIntyre *and* N. Hansen, *Hughes Aircraft Company, Culver City, California.*

Several alternative tactical aircraft systems are to be compared on their ability to accomplish specified interdiction and air superiority objectives. A set of sorties are specified to cover the tactical situations of interest. Effectiveness data are computed for each aircraft system on each of the sorties using Air-to-Air and Air-to-Ground effectiveness models. Other data computed for each sortie are the aircraft attrition, cost, maintainability and reliability. Two models are utilized to organize the data on the aircraft systems in a form which will aid the decision maker. These are the Cost and Effectiveness Coefficient Model and the Linear Program Model. The coefficient model combines all the cost and effectiveness results for a given tactical sortie into a set of coefficients for one unit of each type of aircraft system. The coefficient program also prints out cost and effectiveness subtotals for various classifications of the tactical sorties. In addition, the program puts these coefficients on magnetic tape in the form required for input to the Linear Program Model. Inspection of the results will show the type of tactical situation for which a given aircraft is particularly suited. The linear program solutions, which may be obtained using the data from the coefficient model, identify mixes of the tactical aircraft which can best achieve the tactical objectives. Two types of parametric linear program solutions show how the preferred mix varies with relative cost of the aircraft and with changes in the effectiveness requirements.

WA2.6 Evaluation and Optimization of Tactical Aircraft Avionics—Computerized System Design Optimization, J. A. Stember *and* P. C. Lieb, *Hughes Aircraft Company, Culver City, California.*

A design optimization program is presented which evaluates the tradeoffs involved in avionics system design and operation, and identifies that configuration which maximizes (minimizes) the magnitude of a criterion function interrelating system cost, effectiveness and scheduled availability. Optimization is accomplished by means of a computer-oriented algorithm (MSD), based on the method of steepest descent. In this application, the radar, infrared, display, and navigation elements are subjected to tradeoffs of performance, cost, and development delay due to design risk. Performance is expressed as a function of detection and recognition probabilities of an array of targets encountered on tactical missions. The MSD optimization routine, acting as a feedback loop, systematically perturbs variable design parameters in directions which improve the magnitude of the criterion function (system worth). The overall optimization program forces tradeoff variables to be quantified in such a way as to facilitate liaison among design engineers working in different technologies. It also provides the medium whereby management may influence the physical design through its choice of a criterion function. Finally, the MSD routine generates candidate design configurations which might not have been considered without the aid of a comprehensive digital computer program.

WA2.7 A Dynamic Model of Tactical Air Warfare, E. Brodheim, I. Herzer, *and* L. Russ, *Columbia University, School of Engineering and Applied Science, New York 27, New York.*

In a limited war, air strikes against tactical targets are generally launched in the form of shoot-look-shoot attacks. Both sides use damage assessment as an aid in decision-making. Given certain objectives such as, for example, the minimization of aircraft losses or sorties flown per target destroyed, the offense must make optimum choices among the vehicles and tactics at its disposal at each stage of the battle as a function of certain state variables which describe that stage. Similarly, the defense will choose its salvos so as to optimize its policy with respect to some measure of effectiveness. A dynamic programming algorithm forms the core of a model representing a tactical situation of this type. The model has proven to be useful for rapid evaluations of offense/defense interactions. Since relatively little attention has been paid in the literature to the role of command and control centers, both as targeting options for the offense and as determinants of defensive effectiveness (multiple salvos, target handling capability, etc.), this model has been used specifically for studies of the control function and the means to keep it operative (hardening, redundancy). The measures of system effectiveness discussed in the paper are derived from distributions which are obtained directly from the program, obviating the need for Monte Carlo methods. A cost-effectiveness analysis of hypothetical defense and offense system alternatives is presented and further applications and extensions of the model are discussed.

WA2.8 Air-to-Air Combat Analysis Model, R. L. BLINKENBERG, *Lockheed-California Co., Burbank, California.*

The recent interest and emphasis on air-to-air combat has prompted the development of a model to predict the outcome of an air battle as a function of the weapon systems' capabilities and tactical logic employed. A computer program for this model has been written for the IBM 7094 digital computer using the FORTRAN IV programming language. The simulation program is composed of a trajectory model and a combat model. The trajectory model comprises a set of aerodynamic equations operating in three degrees of freedom. The combat model is composed of the combat logic and the combat monitor. The combat logic involves the attack sequence, the tactical logic, and performance considerations. The combat monitor involves the kill criteria and elapsed time considerations. This is a one versus one combat simulation with two distinct closed logic loops—each aircraft reacts to the others' trajectory and capability. This simulation program may be used to evaluate weapon systems, general tactics and specific tactical maneuvers, or to determine requirements for advanced systems. This program may also be used to determine the relationship of weapon system performance to air-battle outcome and linked to a war game model to provide estimates of combat attrition parameters.

WA2.9 Strategic Aircraft Weapon Allocation and Force Sizing Models, SAMUEL C. COLWELL, *The Boeing Company, Seattle, Washington.*

This paper describes a dynamic programming method to (1) determine the optimum (in terms of "mission effectiveness") mix of offensive and defensive weapons to place on a penetrating strategic aircraft, and (2) determine the minimum force size necessary to attack a particular set of targets. The weapons are gravity bombs and three types of missiles. The missile types are strictly offensive, strictly defensive, and a missile which can be used for both purposes. The effectiveness of the offensive weapons are described by their single-shot kill probability and their reliability, while the effectiveness of the defensive weapons are described in terms of the defense to which it applies. If the defense is an area defense, the effectiveness is the survival of the aircraft versus the penetration distance as a function of each weapon added. If the defense is about the target complex, the effectiveness is the survival of the aircraft versus the number of targets attacked as a function of the number of weapons. The force sizing model then uses the optimum mission effectiveness, flight profiles, payload, range data, availability, and total number of targets in a dynamic programming multistage process to minimize the aircraft cost function.

WA2.10 Battle Space Exhaustion Analysis, L. R. WHITE, *The Boeing Company, Seattle, Washington.*

In an engagement between a collection of attacking vehicles and defense system interceptor missiles the positions of successive intercepts or sets of intercepts move progressively forward, under certain conditions, until the battle space is exhausted i.e., the target vulnerability zone is penetrated. An exploratory analysis has been made in which the defense system is assigned the capability to position and simultaneously detonate interceptors in groups of k. The game is analyzed wherein the offense can choose the spacing between attacking vehicles and the defense can choose both the value of k and the spacing between successive groups of k interceptors. The game payoff is the number of intercepts corresponding to battle space exhaustion. Optimal defense and offense choices together with the corresponding game payoff values are determined as a function of vehicle velocity ratio, available battle space, and the minimum spacing constraints imposed by vehicle vulnerability.

WA3.1 The Shortest Route Problem Under Either Concave or Convex Shipping Costs, WILLARD ZANGWILL, *University of California, Berkeley, California.*

The shortest route problem is to find the most inexpensive path through a network of nodes. There is an amount of material r available at the source node which must be shipped through the network to reach the destination node in the cheapest possible manner. This problem has been widely explored when the shipping cost from any node to another node is a linear function of the amount shipped between the two nodes. However, in many applications the shipping cost is not linear. When all the shipping costs are concave functions, it is possible to formulate efficient algorithms to find the cheapest path. For the concave cost case a transformation is developed which reformulates the concave cost problem as a linear cost problem. The concave cost situation can then be solved by the standard algorithms for linear cost shortest route problems. In the concave cost case the optional solution has the interesting property that the amount to be shipped r might be split into several smaller shipments. This observation coupled with the requirement that the amounts to be shipped must be integral permit solution of the convex cost case by standard methods.

WA3.2 Integer Programming Methods Applied to an Air Transport Problem, ERIC LEESE, *Canadian Forces Headquarters, Operational Research Division, Ottawa 4, Ontario, Canada.*

The problem considered is to minimize the cost of moving specified amounts of freight between pairs of terminal points, subject to certain constraints. Service aircraft and commercial carriers are available to move the freight. The problem is formulated as an integer programming problem. Three methods of solution are compared. These are: (a) Balas's backtrack method, (b) Thompson's Stopped Simplex method, and (c) Gomory's method. Computer storage requirements and running times are compared, for the three methods, for each of a number of specific examples.

WA3.3 Finite-State Machine Models of Traffic Systems, LUCIEN DUCKSTEIN, *The University of Arizona, Tucson, Arizona.*

The purposes of this paper are: First, to illustrate how the theory of finite-state machines can be used as a general tool to describe a wide variety of traffic situations; second, to discuss the merits and applications of such a representation. Examples corresponding to several aspects of traffic flow theory are presented. In particular, one example deals with the microscopic aspect (car-following approach with various sensitivity coefficients); another example, with the macroscopic aspect (shock wave formation and control); still another example, with the control aspect (an intersection with left-turn signals). Experimental data are used, whenever available, to justify the models. Theoretical advantages to a finite-state machine modeling, are: a) the problems must be defined with precision; b) only a minimum number of 'a priori' hypotheses are necessary; c) the passage to certain stochastic models is fairly easy. There are also experimental advantages, namely: a) once the model is established, simulation studies are easily implemented; b) the incorporation of empirical data, such as obtained from human factors studies, offers no difficulty. To conclude, the proposed modeling method offers one step toward a general system representation of several areas of traffic flow theory.

WA3.4 The Tradeoff Between Lives and Driving Time,

Richard L. Goen, *Stanford Research Institute, Menlo Park, California.*

An outline is presented of a rational framework for the selection of appropriate speed limits. Present methods rely on such artifices as the 85th percentile speed and on various secondary criteria. The selection of speed limits is seen to involve a tradeoff between driving time and traffic fatalities, primarily. An estimate is made of the effect on traffic fatalities of changes in the distribution of speeds to provide a basis for illustrating the tradeoffs. The effect on traffic fatalities of reductions in speed is then related to the increase in driving time.

WA3.5 Evaluation of Deterministic Single Lane Traffic Flow Models,

Adolf D. May, Jr., *and* Hartmut E. M. Keller, *University of California Berkeley, California.*

Deterministic traffic models based on the extended car-following equation of Gazis, Herman, Rothery

$$\ddot{x}_{n+1}(t+T) = \alpha \frac{\dot{x}^{m}_{n+1}(t+T)}{[x_n(t) - x_{n+1}(t)]^{l}} [\dot{x}_n(t) - \dot{x}_{n+1}(t)]$$

were investigated. Using different exponents for the sensitivity influence factors, speed of the leading car and spacing between cars, the differential equation was solved to obtain the speed-density relation. By transformation of the equations they could be tested by linear regression and correlation analysis. Existing theoretical and empirical models could be identified to be described by the car-following differential equation (i.e., for $m = 0, l = 1$, one can obtain the Greenberg model.) A data set of the Eisenhower Expressway in Chicago was tested by this procedure. The optimization of the correlation coefficient depending on the exponents of the sensitivity parameters was used to define the best models. Engineering judgment was applied to validate these models on the basis of traffic characteristics such as jam density, free speed, and maximum flow.

WA3.6 Planning and Optimization of Martime Operations,

Ernst G. Frankel, *U.S. Department of Commerce, Maritime Administration, Washington, D.C.*

A recently developed fleet simulation provides a powerful tool for the analysis of ship operations. The work reported here establishes a cost effectiveness model for shipping operations which permits feedback of dynamic parameters affecting optimum requirements of design for future replacement vessels. The criterion introduces physical, operational, human, and economic factors and uses a maximum ranking format to define the relation of the variables to the system objective. An advanced search theory technique is applied in the optimization computation. Other methods of maximization are discussed as are also the implications of integration of shipping with inland transportation and continuous flow termini.

WA3.7 Aircraft Dependability Evaluation and Logistics Planning Model, HENRY B. SORKIN, *Douglas Aircraft Company, Long Beach, California.*

A "Monte Carlo" computer program has been developed which simulates aircraft flight scheduling in order to determine the required ground support effort. It attempts to answer the escalating demands for realism in the quantitative interpretation of aircraft maintainability and reliability for purposes of design analysis and logistics planning. Application of this model consists of two phases. The initial submission considers resources which are dependent upon the maintenance actions required by each of the aircraft's components. Resources consist of quantities of flight personnel, maintenance personnel of various specialties both on the flight line and at field shops, and inventories of component spares, equipment, facilities. The output, therefore, defines the average usage and the most critical demand on each of these resources as the result of the aircraft's inherent dependability. When the resource quantities are subsequently constrained by information obtained from the initial computer run, a second submission delineates system bottlenecks and aircraft queues resulting from the depleted resources. From this information it is possible to interpret the adequacy of the aircraft design related to the resulting burden of logistics support. Program usage to date includes analysis of various tactical transport and training aircraft.

WA3.8 Mathematical Model for Estimating Queuing Characteristics Resulting from Capacity Increases, ADOLF D. MAY, JR. *and* HARTMUT E. M. KELLER, *University of California, Berkeley, California.*

Major attention has been given today to the increasing of capacity of critical bottlenecks through surveillance and control techniques. Measurements of the effect of these capacity increases on queuing characteristics have been primarily obtained from empirical studies using actual field data. The authors of this paper have developed a generalized mathematical model which permits the estimation of a number of queuing characteristics, when the demand pattern and the capacity level is given. The capacity level is to be assumed constant, while the demand pattern is assumed to be triangular or trapezoidal. A computer program for the problem has been developed and examples showing the effect of increasing the bottleneck capacity on such queuing characteristics as duration of queue, total delay, vehicular waiting times have been undertaken.

WA3.9 The Role of Air Transportation in the Growth of Underdeveloped Nations (Brazil, a Case Study), WILLIAM E. DICKISON, *279 Blair Drive, Fairborn, Ohio.*

The role of air transportation in the growth and development of interior Brazil is discussed. For centuries Brazilian trade and communications were carried on entirely by coastal shipping or by mule train over bad roads and trails. In addition most of Brazil's 24,000 miles of railroads are short-haul east-west lines which penetrate inland only a short distance from the coast. The coming of the air age is rapidly changing this state of affairs. Air transportation has enabled development to take place in the previous inaccessible interior. The locations and distribution of all existing air-fields are given with the capacity to handle various transport aircraft. Cost effectiveness comparisons are made with competing types of transportation. Since World War II governments have become increasingly development minded. Air transportation has assisted in speeding up this development by largely overcoming inadequate and crude communication and transportation facilities, especially in remote areas. The effects of government policy on air transportation is also discussed.

WA3.10 Allocation of Transportation Units to Alternative Trips—A Column Generation Scheme With Out-of-Kilter Subproblems, M. R. Rao *and* S. Zionts, *U. S. Steel Corporation, Monroeville, Pennsylvania.*

The problem of allocating transportation units to alternative trips can be solved by linear programming. However, the solution obtained by linear programming has three shortcomings: 1) the solution obtained does not have an integer number of trips; 2) the optimal solution may have sets of disconnected cycles; and 3) problems of considerable size will be intractable because of the vast number of variables and constraints. In some applications it has been found that shortcomings 1 and 2 are not serious but the third one, namely the size of the problem, presents considerable difficulty and an attempt is made to overcome this. This paper describes an approach—a column generation scheme with out-of-kilter subproblems—which reduces the size of the problem considerably. An algorithm for the method is given and it is proved that the algorithm solves the problem in a finite number of steps. Early computational experience with this method is very encouraging.

WA3.11 Optimum Common Carrier Terminal Locations, Robert S. Scott *and* David R. McCullough, *New York State Office of Transportation, Box 7023, Albany, New York.*

The optimum location for a terminal must take into account such factors as passenger travel time, relocation cost, "sunk" investment, land use, and coordination with other forms of transportation. This paper will give primary attention to passenger travel time and then consider other factors. Using a system of travel analysis zones complete with trip origins by mode of travel and minimum path trees, the analysis zones are rank ordered by minimum passenger travel time for each mode of travel. Only the top few zones in these rank ordered lists will be considered as possible terminal sites. The above abbreviated lists are further reduced by the rejection of certain zones for urban planning reasons. Finally, the benefits accruing from location or relocation in one of the desirable zones are balanced against the costs of erecting the terminal in that particular location. A computer program has been written to compute total passenger travel time to an analysis zone and to rank order the zones by minimum travel times. This computer program has already been used in the Buffalo, New York area and is ready for use in other areas where suitable input data is available. This program also promises to be a useful tool for other planning problems where accessibility is a factor.

WA4.1 Estimation of Functional Parameters in Econometric Error Models, T. S. CHIDAMBARAM *and* Y. KURATANI, *Case Institute of Technology, University Circle, Cleveland 6, Ohio*

This paper develops a new estimator, called the "Direction Free Least Square Estimator," for the regression coefficient in a linear regression model where both the dependent and independent variables are subject to observational errors following Gaussian distribution. In the case where the ratio of the variances of the two Gaussian distributions is unknown and hence is to be estimated, the estimator reduces to the Orthogonal Least Square Estimator discussed by Klein. If this ratio is known, we get an estimator which compares well with the corresponding Maximum Likelihood Estimator. The asymptotic properties of the proposed estimator and the Maximum Likelihood Estimator are investigated analytically. In particular formulas for asymptotic mean and variance of the estimators have been derived. Also results of an extensive Monte Carlo study of the small sample properties of the estimators is presented in the paper. It has been found that the asymptotic formulas give a good approximation of the small sample properties even for a sample of size twenty.

WA4.2 The Relationship Between Interstate Variations in the Growth of R&D Activity, IRA HOROWITZ, *Indiana University, Bloomington, Indiana.*

This paper analyzes data derived from a series of 10 reports put out during the past 45 years by the National Research Council on Industrial Research Laboratories in the United States. Though the nature of the surveys does not make the data amenable to precise analysis in any *absolute* sense, some quite interesting *comparisons* can be made with respect to interstate variations in the rates of growth of the number of industrial research laboratories and industrial research personnel. Additional results are presented reflecting the changes, over time, in the "average size," in terms of research people employed, of these industrial laboratories. Correlation analysis is then used to draw some inferences concerning the direction and possible causality in the relationship between interstate variations in the growth of R&D activity and interstate variations in economic growth as measured by various economic variables.

WA4.3 A Method For Economic Comparison of Existing and Proposed Aircraft, R. K. SCHAEFER, JR., *McDonnell Aircraft Corporation, Box 516, St. Louis, Missouri.*

A method of comparing a force-in-being with proposed replacements has been developed. The method quantitatively measures differences in cost-effectiveness as a function of the time period in which the replacements become available. A constant effectiveness model is used as the basis for establishing inventory requirements necessary to meet the desired effectiveness goals. As replacement items become available, they replace the existing item at a rate consistent with their relative effectiveness with the objective of maintaining constant effectiveness throughout the transition period. The number of each item required each year is compiled over the time period of interest. The cost of operating the existing force; developing, procuring, and operating the replacement force; is compiled for each particular year. The present worth of money is used to discount expenditures for subsequent years. Thus, a method to quantitatively account for dissimilar fund expenditure rates is available through a normalized cost estimate which reflects economic effect, risk, future budget restrictions, and other economic restrictions.

WA4.4 The Effect of Forecasting Procedure on System Response, E. T. Alsaker, *Lockheed-Georgia Company, Marietta, Georgia.*

Forecasts are frequently used to establish budgets or other criteria for measuring performance, despite in some cases the doubtfulness of theoretical validity of the forecasting methods used, and in other cases despite use of regression coefficients developed for variables whose ranges in the samples may have been constrained in various unrecognized ways by the effects of prior forecasts on system responses. It is evident that what on the surface appears a well-behaved forecasting procedure may in fact disguise circumstances leading to an operational result that is other than the optimum one desired. Several examples are explored, including the "learning curve" that is widely used in predicting performance. The objective is to arrive at a set of rules that may profitably be observed in determining whether the forecast in question is likely to have a prejudicial effect on system response. What might be done in the typical case to avoid such prejudicial effects on system response is also reviewed.

WA4.5 Generation of Economic and Social Information for Small Areas from Power Utility Data, Ivars Gutmanis, *Public Health Service, Third and C Streets, S.W., Washington, D.C.*

Economic and social data for small areas are difficult to obtain since the geographic area for which the data is desired does not correspond to the regional delineation, judicial or political, for which economic information is systematically collected. In the absence of such data, the desired information is, as a rule, generated by surveys, a relatively expensive undertaking, which precludes continuous systematic data gathering processes. However, the utility companies, especially power utilities, possess information and data which, when systematically handled using linear programming, can be used to obtain a number of pertinent indicators for small areas on systematic and continuous basis. Among these are data pertaining to various types of construction activity; data on the installation of producers durable equipment (P.D.E.), and, therefore, determination of capital stock for manufacturers and service sectors; information for the determination of the level of economic activity in a large number of industry sections, as well as others.

WA4.6 Optimal Issuing Policies in Inventory Management—I, William P. Pierskalla, *Case Institute of Technology, University Circle, Cleveland 6, Ohio.*

We are concerned with generalizations of the inventory depletion model where the inventory deteriorates in time as it remains on the shelf. Once put in use, an item from the inventory of n items has a nonnegative field life, $L(S)$, which is a function of the age, S, of the item upon issuance to the field. The objective is to determine the order of issue that maximizes the total field life of the stockpile. Optimal policies of the form LIFO, last in first out, of FIFO, first in first out, are sought. Earlier authors writing on this subject have placed many restrictive assumptions on the model. These restrictions make the model inapplicable in most real inventory depletion situations. The assumption of one demand source withdrawing items from the stockpile is removed and the case of several demand sources is considered. Next, it is assumed that there is a constant penalty cost, p, each time an item is issued. p can be described as an installation or work stoppage cost. The results for the above cases are given when $L(S)$ is a concave or convex function. A more general type of function is considered. We let $L(S)$ be a concave nonincreasing function for $S \varepsilon [0, t]$ and $L(S) - L(t) - c > 0$ for $S \geqq t$. When $L(S)$ has this form, it provides a good approximation to the general S-shaped curve.

WA4.7 Optimal Tax Splitting Among a Number of Tax Entities, B. ALVA SCHOOMER, JR., *Arthur D. Little, Inc., Cambridge, Massachusetts.*

When income-producing property (such as a business, income real estate, securities, etc.) is closely held, the opportunity arises for tax savings similar to that which occurs when a husband and wife file a joint income tax return. The general principle involved is the division of the income-producing assets (and consequently the income) among a number of legal entities which, for income tax purposes, are taxed independently from each other. Examples of such legal tax entities are corporations and tax trusts. This paper describes a general method for calculating that allocation of income among a variety of such entities which minimizes the over-all income tax paid.

WA4.8 Optimal Operating Policies for Stochastic Service Systems, DANIEL P. HEYMAN, *University of California, Berkeley, California.*

We consider an M/G/1 queuing system operating at equilibrium for an infinite planning horizon with the following costs: R_1 = server start-up cost, R_2 = server shut-down cost, Γ_1 = cost per unit time of an idle server, r_2 = running cost per unit time of the server, h = holding cost per unit time per customer. The problem is to find the optimal number of customers present before the service mechanism is turned on; this number is called n^*. For the undiscounted case, $n^* = [2\lambda(R_1 + R_2)(1 - \rho)/h]^{1/2}$, which is similar to the Wilson formula for inventory problems, where λ is the arrival rate and ρ is the system utilization. When discounting is used, the expected discounted total cost is shown to be convex in n, and simple methods for calculating n^* are available. Next, a control parameter α is introduced which allows the service rate to be varied with a corresponding change in the running cost. Conditions are found which make changes in the service rate desirable, and the optimal control settings are calculated. Finally, finite horizon models are considered, and the dependence of n^* on the horizon is calculated.

WA4.9 Optimal Design of a Stochastic System with Dominating Fixed Costs, SATINDER K. MULLICK, *Corning Glass Works, Corning, New York*

In many cases, manufacturing, for example, large elements of cost vary in proportion to organization activity but there are other organizations in which so-called "fixed costs" are quite dominant. Academic institutions are of this kind and so also are various branches of government, and eleemosynary organizations such as hospitals, where ward staffs tend to remain stable over wide ranges of patient census. Libraries also are organizations of this kind, where the variable expenses associated with acquisitions (excluding expenditures paid for books), cataloging, and library use are quite small per unit of library activity, and are, indeed, trivial relative to the much larger expenditures paid in the form of staff salaries. In such cases executive decisions as to when staff shall be augmented or curtailed become critical to provision of adequate service on the one hand and economical operation on the other. In general, such decisions tend to lag the need for action so that service becomes inadequate in time of rising demand and costs inordinately high when demand is declining. Various mathematical models and decision rules are developed to guide in the optimal design of the library service centers. This approach offers possibilities for more general application to other situations in which fixed costs are dominant, situations which are mathematically intractable because of discontinuities.

WA4.10 The Application of Liapunov's Direct Method to a Problem in the Theory of Utility, D. Boyanovitch, *Grumman Aircraft Engineering Corporation, Bethpage, Long Island, New York.*

In the past few years some mathematical techniques (notably Pontryagin's Maximum Principle), which have been successfully applied to guidance and control problems in the aerospace industry, have found their way into econometrics. This paper presents an application of such a technique, currently used to study the stability behavior of control systems, to a problem in the general theory of utility. The applicability of this technique, known as Liapunov's Direct Method, results from the fact that the problem of the marginal rate of substitution of one good for another good or goods can be formulated as a system of ordinary differential equations. It is shown that 1. the indifference curves can be identified with the system trajectories, 2. the Liapunov function can be identified as the utility function of the consumer, and 3. the singular (or equilibrium) point can be considered as that combination of goods which either gives the greatest or least utility or satisfaction. Furthermore, depending on the character of the Liapunov (or utility) function, a region of stability, i.e. a set of combinations of goods which gives acceptable or unacceptable satisfaction to the consumer, can be determined. This technique has potential applications to marginal analysis, theory of value, trade cycle theory, demand and production theory, and in general to problems which can be formulated in terms of a system of difference-differential equations.

WA4.11 Optimum Strategy for Return of a Nonrandom Customer Competing with Random Arrivals, Milton L. Smith, *Texas Technological College, Lubbock, Texas.*

Queuing theory generally has concerned the service facility and its parameters with the object being to alter the parameters to produce optimal conditions for the service facility. This paper describes the development of a strategy of arrival times for an arriving unit to optimize the strategy for return of a nonrandom customer competing with random arrivals. A finite queuing system with Poisson arrivals and exponentially distributed service times is considered. All arrivals are random except the one particular unit of interest. If an arriving unit finds the system saturated, it must leave. All random arrivals have only one opportunity to attempt entry into the system. The one particular unit can return repeatedly until a vacancy in the system is found; however there is no transmission of information to the unit concerning the appropriate time to effect another attempt. A strategy based upon fixed queue parameters (λ, μ, and N) is developed to gain entrance into the system for the particular unit of interest. This strategy is the elapsed time between an unsuccessful attempt and a reattempt with the object being to minimize the expected number of attempts necessary to gain entry.

WA5.1 Fractional Convolution of a Probability Vector, Edward A. Silver, *Arthur D. Little, Inc., 35 Acorn Park, Cambridge, Massachusetts.*

An important component of many stochastic models, used in operations research, is the number of occurrences (j) of a random event during a time period of prescribed length (U). Often, the probabilities of the various possible values of j can be estimated through the use of: a) empirical observations of the numbers of occurrences in several intervals of length U, and/or b) prior subjective information about the probabilities of the various numbers of occurrences in an interval of length U. However, there are situations (usually caused by physical or economic limitations on the data collection operation) where the empirical data and/or subjective information are based on a basic time length of length T (different from U) and a conversion to an interval of length U is required. If U is an integer multiple of T and events in non-overlapping intervals of length T can be assumed independent, then the desired transformation is accomplished by a straightforward convolution operation. This paper develops a practical approximation method for the situation where U is not an integer multiple of T (in fact, U may not even be as large as T).

WA5.2 Optimal Bayesian Stratified Sampling by Nonlinear Programming, Richard M. Soland, *Research Analysis Corporation, McLean, Virginia.*

The optimum allocation for stratified sampling is studied under the Bayesian assumption that prior information concerning the unknown stratum means is available. The prior information is assumed to be expressed in the form of a multivariate normal prior distribution for the unknown stratum means. The cost of sampling is the sum of the costs of sampling the various strata, and the cost of sampling stratum i is taken to be a constant c_i times the size of the sample taken from stratum i. Not all strata need be sampled. The following allocation problems are formulated and solved as nonlinear programming problems. (1) Minimize the posterior variance of a linear combination of the unknown stratum means subject to a budget constraint. (2) Minimize the sampling cost subject to an upper bound constraint on the posterior variance of a linear combination of the unknown stratum means. (3) Minimize a weighted sum of the sampling cost and the posterior variance of a linear combination of the unknown stratum means.

WA5.3 On Bayesian Confidence Limits for the Reliability of Redundant Subsystems Having Exponential Distribution of Life When Subsystem Tests Are Terminated at First Failure, M. D. SPRINGER *and* W. E. THOMPSON, *GM Defense Research Laboratories, 6787 Hollister Avenue, Goleta, California.*

Bayesian confidence limits are derived for the reliability of a system composed of N redundant exponential subsystems, when subsystem tests are terminated at first failure. The method consists of deriving the posterior probability density function $h(R)$ of the total system reliability R, where $R = 1 - \prod_{i=1}^{N}(1 - R_i)$, and requires direct evaluation of a Mellin inversion integral. The inversion is accomplished and $h(R)$ obtained by summing the residues of the integral at its poles. The poles are all of Nth order, and occur on the real axis at the points $X = 0, -1, -2, -3, \cdots$. From the density function $h(R)$, the distribution function $H(R)$ is derived, from which confidence limits are obtained by numerical inversion.

WA5.4 Bayesian Strategies and Competitive Bidding, DONALD H. WOODS, *University of California, Los Angeles, California.*

A competitive bidding decision game is modeled after an asymmetrically uncertain actual situation. One player knows an asset value for certain, but the other has only a probability distribution on which to act. In addition, both are uncertain regarding each other's bidding strategy. The theory of *non-cooperative two-person nonzero sum games,* although useful in providing a structure for the problem, is not helpful because one player's bidding strategy is dependent on the true asset value whereas the other's is not. On the other hand, Bayesian decision theory provides a systematic framework for synthesizing a *coherent* bidding strategy even when the opponent does not play his "equilibrium strategy." A strategy is termed coherent when the three elements of uncertain asset value, uncertain competitive behavior, and one's own bid are in balance. The subjects are a group of businessmen attending a seminar. Through the use of assessed subjective probabilities, each player's actual judgments regarding competitive behavior are taken into account. The bids are found to be largely incoherent and exploitable, although improvement is noted after switching of roles.

WA5.5 The Stationary Behavior of a Time-Sharing System Under Poisson Assumptions, B. KRISHNAMOORTHI, *System Development Corporation, Santa Monica, California.*

Recently, the author analyzed a Markov chain imbedded in the stochastic process $\{X(t);\, t \geqq 0\}$ where $X(t)$ denotes the number of active channels at time t in a time-sharing system with both interarrival and service times exponential and a finite number of users. In this paper he obtains, using renewal-theoretic arrangements, the limiting distribution of $X(t)$ as t goes to ∞ over all time points. The equilibrium waiting time is also analyzed.

WA5.6 Sequential Decision Problems: A Model to Exploit Existing Forecasters, WARREN H. HAUSMAN, *Cornell University, Ithaca, New York.*

We partition a sequential decision problem into two parts: a predictive model describing the probability density function of the state variable, and a separate framework of decision choices and payoffs. If a particular sequential decision problem is a recurring one, then there may often exist human forecasters who generate quantitative forecasts at each decision stage. In those cases where construction of a mathematical model for prediction purposes is difficult, we may consider using the forecasts and forecast revisions provided by the existing forecasting mechanism. The paper considers a specific class of problem in which improved forecasts of an unknown quantity are available before each decision stage. We hypothesize that forecast revisions may be approximated by a quasi-Markovian data-generating-process. Specifically, we argue from *a priori* reasoning that ratios of successive forecasts will be independent Lognormal variates. A small number of actual forecasters is then studied through analysis of historical data, and the independent Lognormal hypothesis is generally supported. Finally, we illustrate the usefulness of the approach by considering a simplified version of a multistage agricultural supply problem in which requirements are known but product availability must be forecasted until after the harvest.

WA5.7 Individual Choice Behavior and Markov Renewal Processes, D. A. SCHRADY, *U.S. Naval Postgraduate School, Monterey, California.*

The paper develops a descriptive model of individual choice behavior viewed as a perception-choice-reinforcement process and mathematically modeled using the Markov Renewal process. Use of the Markov Renewal process makes time an explicit parameter of the model. The model provides for reinforcement, but does not allow learning. Population subgroups are created to recognize basic individual differences in choice behavior. Within each subgroup, reinforcement is exhibited both in the choice probabilities and in the renewal distributions which generate the times between decisions. The model thus developed was applied, with very satisfactory results, to data on individual choice behavior with respect to seeking dental care. A further analysis indicates how the model may be used to predict measures of system performance dependent upon individual choice behavior.

WA5.8 Finite Source Queuing Models, N. K. JAISWAL, *Case Institute of Technology, Operations Research Group, Cleveland 6, Ohio.*

Queuing models in which the units emanate from at least one finite population, to which they return after getting service, are termed finite source queuing models. The simplest model of this type has application to the machine interference problem. Previous work on this model is reviewed and the solution is discussed in detail by the use of the supplementary variable technique and the renewal theory. Some generalizations are discussed with special emphasis on the allocation of priorities if there are more than one class of units emanating from different finite sources or from the same finite source. The multi finite-source models and the single finite-source models differ unlike the infinite-source models. Some problems for further work are pointed out.

WA5.9 Some Applications in Relating Growth and Failure Processes, GEORGE MICO, *Union Carbide Corporation, 270 Park Ave., New York, New York.*

In a number of situations the functional form of a growth process is to be studied in terms of a failure process or failure processes in terms of growth processes. The difficulties arise in that estimation may be determined in one process while it is the other process that is of importance. To illustrate this point, two examples are given of estimating with growth processes when in the first case it is the failure process that is of importance and in the second it is the growth process. This study relates the analysis of the failure process to the growth process through the intensity functions. Specifically the intensity function $\mu(t)$ of a growth process is studied in relationship to a given failure intensity $\lambda(t)$ by, $\mu(t)=\lambda(t)/(e^{\int_0^t \lambda(t)dt}-1)$. In this situation there exist certain equivalences between the two processes. Some of the limitations of these equivalences are given with respect to the estimation problem.

WA5.10 Cost Balancing of a Multiservice Queueing System with Nonhomogeneous Arrivals,

RONALD LESSING *and* EARL D. LOWERY, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.*

A typical office queueing system exhibits an overall cost composed of two basic components, i.e., the cost of providing service and the cost associated with people waiting for the availability of servers. This paper assumes that the system exists to provide an interview (type 1) and a development (type 2) service for two classes of arrivals. The first class of arrivals may be served by either a semi-professional or wholly professional employee. The second class of arrivals requires a service that may only be rendered by professional employees. The model includes provision for the transfer of some of the semi-professional workload to professional employees, but not vice-versa. Dollar costs are assigned to the waiting time of the two classes of arrivals, and the waiting time costs plus the cost of providing servers are summed to obtain a total cost which is optimizable.

WA5.11 On the Number of Tasks Performed by a Repairable Machine,

MECKINLEY SCOTT, *University of Alabama, University, Alabama.*

Consider a machine subject to breakdown. The machine, if working, performs a certain kind of task and the probability of completion of a task in ξt is $\lambda\xi t+o(\xi t)$. The running time of a machine is a random variable following exponential distribution and so is the repair time. Under these assumptions, the generating function, mean, variance, and certain conditional expectations of the number of tasks performed by the machine during $(0, t)$ are obtained. It is shown that the distribution of the time between two successive performances of a task is a mixture of two exponential distributions.

WA5.12 Design of Filter to Extract True Signal s(t) from f(t) = s(t) + n(t) where f(t) is Time Series Generated by Stationary Random Process,

G. G. HINGORANI, *Northern Natural Gas Company, 2223 Dodge Street, Omaha, Nebraska.*

Given is a perturbed signal $f(t)$ which is the sum of a true signal $s(t)$, and a perturbing noise $n(t)$ i.e. $f(t)=s(t)+n(t)$. The goal is to design a filter such that, when we operate on $f(t)$, we obtain as well as possible the true signal $s(t)$. It is assumed that the statistical properties of a random process, which generates the time series $f(t)$, do not vary with time; i.e. the analysis holds for stationary random processes.

WA6.1 The Design of an Engineering Management Game, M. A. Glatt, *McDonnell Aircraft Corporation, St. Louis, Missouri.*

The establishment of the electronic computer as an engineering tool and its subsequent ultilization in general office operation has recently been extended to the area of managerial decision-making. In this application, the computer solves a mathematical model that simulates the conditions and problems faced by managerial personnel. By this approach, it is hoped to strengthen the management-decision-making process through practice by having available the results or consequences of decisions. These simulations of business games that concentrate on the broad aspects of a business are receiving wide publicity and corporate attention. In this age of technology, the success of a company is measured largely by the success of its engineering effort. Although computers evolved directly from the needs of engineering research, few instances are recorded of their direct application in the improvement of management decision-making in an engineering function. There is an urgent need to improve the decision-making closer to the working level. Too frequently the training and development programs at this level are imperceptible, intermittent, or too broad in scope. It is the purpose of this paper, therefore, to explore, construct, and recommend a business simulation game for the express purpose of training and developing managerial personnel engaged in an engineering activity. Specifically, the objective is to construct a model that simulates activities and problems frequently occurring in the management of an engineering department. The interests of such a department are diverse, and among other things, are directed toward projecting budgets, establishing research and development programs, hiring personnel, assigning jobs, meeting schedules, submitting bids, and "getting along" with people. It is the intent to combine these and other activities into an exercise for training engineering management. In summary, this paper has attempted to show that a functional game closer to the working level is feasible, practical, and useful. This was achieved by carefully selecting essential characteristics of a real engineering department and combining them in a realistic manner.

WA6.2 Desiderata for a Flexible Management Game, Richard F. Barton, *School of Business, University of Kansas, Lawrence, Kansas.*

Games are used both for training and for research. Training games have been complex, with rich environments and behavior. Experimental games have been simple and sterile, but rigorous from an experimental point of view. Different classes of subjects participate in each type of game. The most interesting subjects play management rather than experimental games. A challenging research objective is to adapt management games and their more interesting subjects to serve experimental purposes. To do this a flexible management game is needed. This paper discusses the basic requirements and some additional desirable features for a flexible management game useful for research. The flexibility contemplated includes adaptability to many industries and to a variety of simulated environments, to both non-computer runs and all-computer runs, and to the study of individual as well as team behavior.

WA6.3 The Grid Charting Technique for Management Information Systems, Gordon Thomas Shahin, *The Ohio State University, Columbus, Ohio.*

The primary purpose of this study was to evaluate the grid charting technique as a model for the analysis and design of large-scale integrated management information systems. To accomplish the primary purpose of the study, the following specific objectives were established: (1) to develop and teach a theory of management information systems and the grid charting technique, (2) to measure the degree of usefulness of the theory of management information systems and the grid charting technique, (3) to identify the advantages and disadvantages of the grid charting technique, (4) to identify modifications made to the grid charting technique, and (5) to identify factors limiting the use of the grid charting technique. The establishment of the Directorate of Data Systems in the Air Force Logistics Command offered the opportunity to subject the theory and the grid charting technique to a test of results in large-scale management information systems. This satisfied the first objective. The second objective was accomplished through a questionnaire sent to these employees. The third, fourth, and fifth objectives were accomplished through interviews with a sample of these employees. The study showed that the grid charting technique as a model for large-scale management information presents the entire system and its details in an easily comprehensible form, can be manipulated, and shows the effects of systems changes.

WA6.4 A Model for the Effectiveness of an Activity as a Function of the Personnel Rotation Policy, J. J. Martin, *USN, Staff, Antisubmarine Warfare Force, Pacific, Fleet Post Office, San Francisco, California.*

Individuals, upon reporting to a new job, generally undergo some period of training during which their effectiveness, measured in appropriate units, increases with time according to a learning curve. Activity effectiveness, when regarded as a weighted average of individual effectiveness, thus varies with time as personnel arrive and depart in accordance with some rotation policy. Assuming that arrivals to the activity are random events with the interarrival time density function $f(x)$ and that an arrival triggers a departure, thus maintaining a constant manning level, the selection of a personnel rotation policy is equivalent to choosing $f(x)$. It is assumed that the population of individuals has a mean learning curve which can be expressed as a finite sum of exponential functions and a model is developed which yields the average activity effectiveness at a random time in terms of the Laplace transform of $f(x)$. The model is then extended to include the possibility of batch arrivals. This activity effectiveness model is suitable for numerical calculations and provides a useful tool to assess the effects of various rotation policies. It is particularly applicable to organizations such as military activities, which have a large-scale, routine turnover of personnel.

WA6.5 Some Entrepreneurial Demands on Quantitative Science, Herbert Ruderfer, *Mathematical Analysis, IBM Corporation, Armonk, New York.*

Problems in the business world have different characteristics from problems in the hard sciences. One characteristic that produces a great difficulty is the dynamic state of the hypothesis structure in business model building. This, together with a demand on "immediate" solution, places great emphasis on the speed of problem definition and on the rapid translation of business mechanics into a computer oriented quantitative language. In addition, the cost considerations of solution demand careful study. By exploiting the lack of precision of business data flexible "solutions" can be achieved that respond to the fluid state of the business. Unfortunately trained personnel are lacking with the requisite skills to do this. A program is discussed which is directed towards raising the level of skill of the quantitative scientists in the business environment. The following areas will be covered: (1) Selection of Personnel; (2) Rotation of Personnel among Functional Areas of the Business; (3) Organization of Programmer-Systems-O.R. teams; (4) The Accessible Computer; (5) Elegance Through Flexibility; and (6) Computer-Oriented Math. Courses.

WA6.6 Business Operations in a Real-Time System, Jerry Scott, *Southwestern Bell Telephone Company, St. Louis, Missouri.*

The effects of a real-time Business Information System on the operation of a business office are presented. Consideration is given to manpower requirements; accuracy and speed of obtaining information for customer queries; and flow of work from the customer request for telephone service to installation of that service. As in many real-time systems priority levels are assigned. Use of simulation techniques have been used in analyzing and designing and the Business Information System.

WA6.7 Scientific and Engineering Manpower Projection and Cost Model, Harvey B. Safeer, *Research Analysis Corporation, McLean, Virginia.*

This paper describes a model showing the interactions among the factors relevant to Federal financing of academic research, facilities for science, and graduate education in the sciences. It contains a first approximation to a workable model for projecting production of scientific and engineering manpower and the associated costs to the Federal government for direct student support, research grants and facilities expenditures. The model is designed for use in assessing the implication of alternative Federal expenditure policies (i.e., direct vs. indirect student support) on scientific and engineering manpower production. When implemented, it should provide the policy planners with a quantitative tool which would not generate policy, but would enable them to realize the impact of policy decisions.

WA6.8 On the Application of a Specialized Control System for Scientific and Technical Information Centers, Stanton E. Mintz, *Litton Industries, Van Nuys, California.*

A scientific and technical information center (STIC) is characterized as a large processor of documents (or full text) and facts (partial text). Established STIC's are usually organized and set-up along lines which resemble fabrication or production operations. Raw material is represented by documents, these in turn are subject to processing and conversion to a storable media (micro-file, tape or disc storage). The material that flows through "assembly lines" is paper—not hardware. Operations along main line flows are not paced by machines, conveyors or a control processor. In "hard line" industry, a part is subject to machining or some type of machine processing. The pace along the line is governed by the speed of a machine, belt or processor. This pacing mechanism performs a forcing function on all operators along the line. Belt speeds can be adjusted according to the standard (work) for the operation and a whole line can literally be balanced by the adjustment of machine or belt speeds. This is not the case where information or data in large quantities must be processed and controlled in an orderly manner. Lines have been set up for the mass processing of documents; advanced electronic or optical equipment have been employed to speed up the processing, but many of the gains which should have been realized through the utilization of such equipment are lost due to the lack of a system which can control and monitor the entire process. A highly specialized production control system was needed to artifically pace lines and provide precise in-process control. Data Line Control was designed specifically to meet these requirements. Data Line Control provides for batch (continuous) processing documents and/or data at predetermined time intervals, at pre-determined cycle times, and at variable operator proficiency. The system calls for the establishment of a master time table for each flow or line. Batch sizes and release intervals are also computed for each line. Data Line Control paces all operations along the line and provides for a simple method of in-process control. The system itself can be operated and maintained by clerical personnel.

WA6.9 Research Note: Comments on Product Cost Optimization, ROBERT B. MCCLELLAN, *24233 Welby Way, Canoga Park, California.*

This paper discusses product optimization in terms of definitions and potential application. General requirements are stated and a possible procedural approach is outlined. An example is given with design, material and fabrication cost data in abbreviated formats. An optimization search routing for the example product is outlined. Concluding comments outline a general course of action.

WA6.10 Product Performance Model (PPM), CHARLES MCCRACKEN, *Martin Company, Orlando Division, Orlando, Florida.*

The Product Performance Model is based on the fact that a system must be available, compatible with the operational environment, and operate reliably as long as required. The model output is the probability that the mission will be successful. The PPM figure of merit is not a laboratory or test number, but the probability of success in the actual operating environment, which may be a combat situation where an active and intelligent enemy is doing everything in his power to make the system fail. The model has three branches: designed availability, compatibility and reliability. The compatibility branch is used to determine the probability that the system will be compatible with its total environment. The reliability branch is used to calculate the probability that the system will operate within acceptable tolerances throughout the mission. The product of these three probabilities is called the "performance" of the system. The principal advantage of PPM is that it provides a realistic estimate of the combined effect of enemy action, hostile natural environment, logistic difficulties and equipment failures on the potential or "design" effectiveness of a system. Our experience with PPM indicates that this model can provide a better estimate of how well a system will actually work in the "real world" than is obtainable through older and more optimistic evaluation procedures. Also, PPM makes it easier to allow for the effect of human error and administrative delay on the theoretical capability of a weapon system. The model can be applied economically to single point problems as well as parametric runs. The model can be used by people who are not specialists in mathematics or operations research.

WA6.11 The Evaluation of Potential New Product Alternatives, MARSHALL FREIMER *and* LEONARD S. SIMON, *The University of Rochester, River Campus Station, Rochester, New York.*

In evaluating new product opportunities through the use of a rating scheme, account must be taken of the fact that the individual factors on which the product is being assessed interact in producing an overall result. A score for a product may be thought of as a point in n dimensional space in which are located two density functions, one representing scores of successful products and the other unsuccessful products. Linear discriminant analysis provides the means for identifying the likelihood ratio of success to failure for any given potential product (point). The question then arises as to whether to accept the decision dictated by the discriminant analysis or to collect more information concerning the location of the point. Both a posterior and a preposterior distribution can be obtained, yielding the value of additional information and thus determining whether to make the decision now or to postpone it.

WA7.1 A Parametric Method for Solving Certain Nonconcave Maximization Problems, KLAUS RITTER, *University of Wisconsin, Madison, Wisconsin.*

In this paper maximization problems with linear inequality constraints and different types of nonconcave objective functions are considered. By introducing an appropriate additional linear constraint the given problem is transformed into a parametric quadratic problem, the parameter appearing in the objective function as well as in the constraints. A method is given which yields the optimal solution of this parametric problem as a continuous function of the parameter. Since it can be shown that the absolute maximum of this function over a finite interval is equivalent to the optimal solution of the given maximization problem the original problem is reduced to a one-dimensional maximization problem. In special cases the parametric quadratic problem becomes a parametric linear problem.

WA7.2 Methods for the Solution of the Multi-dimensional 0/1 Knapsack Problem, H. M. WEINGARTNER *and* DAVID N. NESS, *Massachusetts Institute of Technology, Cambridge, Massachusetts.*

In the knapsack problem, given the desirability of each of a number of items, one seeks to find that subset which satisfies a constraint on total weight. The multi-dimensional variant imposes constraints on additional variables of the items; the 0/1 specification means that an item is either taken or not, i.e., multiples of the same item are not considered, except possibly indirectly. Traditionally the

1-dimension knapsack problem is solved by means of dynamic programming. The multi-dimensional problem is usually reduced to a one-dimensional one by use of Lagrangian Multipliers which, however, do not generally yield the exact solution to the problem posed. The present paper considers methods for obtaining the exact solution to the problem, and not an approximate one. Additional algorithms are developed which are applied within a dynamic programming framework. Given these, the object is to obtain solutions efficiently, and in attaining this goal heuristic methods are employed. Efficiency of the methods is based upon the use of an interactive computer system in which the heuristics of the problem solver are applied and changed as the character of the solution process evolves. The project was conducted within the Compatible Time Sharing System of M.I.T.'s Project MAC. The problem arises in the context of capital budgeting, but has obvious applications in a variety of other areas. The methods have been employed for solving numerical problems with as many as 105 items, the parameters having been obtained from industrial applications.

WA7.3 A Game Theoretic Approach for Approval of Engineering, Design, and System Change Proposals, R. A. Nelson, *Vitro Laboratories, Silver Spring, Maryland.*

Classically, the evaluation of engineering, design, and system change proposals has been executed in a highly subjective manner. Any objective analysis has been largely limited to an engineering review which estimated changes in performance characteristics of a modified equipment. Recently, attempts have been made to increase the objectivity of these evaluations. The number of variables affected by a proposed change, whether it be engineering, design, or system oriented, are usually so numerous and unquantifiable using existing data that an analysis providing decision criteria with certainty is impossible. Even successful application of statistical probability techniques to cost-effectiveness studies of change proposals are few. Most decisions concerning change proposals are presently made in the face of uncertainty. The application of the theory of games to this decision-making situation seems plausible; the pessimistic outlook will help provide a decision from a number of alternatives that will maximize the minimum benefit when the approved change proposal is implemented. It will be shown how each of the important variables that are affected by the proposed change can be selected and a rating index can be given for each of these variables. Examples of transforming these rating indices into elements of a payoff matrix will be given. This application of the theory of games should be a useful tool until the time when data accumulation and analysis techniques are advanced enough to allow the change proposal acceptance decision to be made in a highly objective manner.

WA7.4 Cutthroat Games, Steven L. Jordan, *Research Analysis Corporation, McLean, Virginia.*

A natural generalization of a two-person zero-sum game is a "cut-throat game," one in which both players have directly opposing goals. Certain properties of zero-sum games are shown to hold for cutthroat games. Noncooperative n-person games are broken into equivalence classes according to preference patterns. The normalization of a cut-throat game to a zero-sum game is justified: a game is cutthroat if and only if it is equivalent to a zero-sum game; the equilibrium points of equivalent games are naturally related. The sup-inf values of equivalent games are discussed in detail. Because of interpersonal comparisons of utility, the tools developed in this article are not useful for analyzing n-person cooperative games.

WA7.5 Multiperson Negotiation Games, ROBERT L. SWINTH, *Carnegie Institute of Technology, Schenley Park, Pittsburgh, Pennsylvania.*

Considerable work has been done on understanding the exchange process between two people—Game Theory, Bargaining Theory, Interpersonal Relations Theory. Much less is known about multiperson negotiations. This is especially true of the type of negotiations in which there is an intermediate stage in the exchange process where one class of participants first converts the resources it has obtained from the other class on promises into valuable services. For example: politicians make competing promises for votes, the electorate gives its votes to one of the candidates, the man elected uses the resultant power to dispense services to himself and the people. This is more complex than the simple process of exchange where A gives B something (like money) and B gives A something (goods)—whether it be interperson or multiperson. The author created a game with two classes of players (similar to the politicians-voters classifications). The A class of players first made promises to the B class of the value they would give for the resources of the B class. After the people in the B class had made their choices each member of the A class would convert the resources he obtained into value and distribute it as he saw fit. The author studied behavior in this situation over a series of trials in order to understand the decision-making processes of the participants in the B class. He found that a decision theory model based on probabilities of past rewards as a percent of offers did not predict behavior any better than a random model based on random choice. On the other hand, a computer simulation model based on an assessment of the reliability of others (in a go-no sense rather than probabilities) and on one's willingness to take risks predicted behavior well (significantly better than the decision theory model and the random model).

WA7.6 The Utilization of Linear Programming to Obtain a Long-Term Capital Expenditure and Operating and Maintenance Plan, STUART C. HARRIS, *Anathon Inc., 11 East 36th Street, New York, New York.*

Linear Programming is the major component of a mathematical model used for obtaining a long-term capital expenditure and operating and maintenance plan for a 100 building complex which is expected to double in the next 40 years. The model utilizes the existing facilities to determine the least cost plan required to satisfy the predicted heating and cooling demands. The time period was segmented into nine intervals and piecewise linear approximation was utilized to lessen the impact of non-linear functions. Since considerable uncertainty is contained in long-term predictions of future heating and cooling loads, and equipment, fuel and labor costs, the program evaluates the sensitivity of the final plan to these loads and costs. It also provides for the updating of the plan as new data become available.

WA7.7 Some Truncated-Enumeration Methods for Solving Integer Linear Programs, FRED GLOVER, *University of California, Berkeley, California.*

The paper examines common and contrasting notions underlying some recent integer programming algorithms developed by Egon Balas, Norman Driebeck, G. L. Thompson, and the author. Variations on these algorithms are introduced in terms of a unifying framework, and some results concerning ways of circumscribing the feasible integer solution space for certain special kinds of problems are also presented.

WA7.8 Linear Programming Solutions for Separable Markovian Decision Problems, GUY T. DEGHELLINCK *and* GARY D. EPPEN, *University of Chicago, Chicago 37, Illinois.*

This paper is concerned with the linear programming solutions to sequential decision (or control) problems in which the stochastic element is Markovian and in which the objective is to minimize the discounted sum of expected costs when a discount factor λ, $0 \leqq \lambda < 1$ is used. In particular it considers systems that are discrete in time and space and which have a finite state space. Within this set of systems, it deals with a class of "separable" problems for which it is possible to define a "reduced" linear programming problem whose solution yields the optimal operating policy and the shadow prices for states of the system. The reduced problem involves a substantially smaller number of variables than the usual linear programming formulation of these problems, and the conditions necessary for a problem to be separable are satisfied in a number of important problems. The use of the "reduced" problem makes it possible to obtain results for problems of a practical size with readily available linear programming computer codes. Two well known example problems are solved with the "reduced" problem to illustrate the use and utility of this approach.

WA7.9 A Sufficiency Solution of the Traveling Salesman Problem, MILTON ASH, *E. H. Plesset Associates, 2444 Wilshire Blvd., Santa Monica, California, and* JOHN STAUDHAMMER, *System Development Corporation, Santa Monica, California.*

This paper presents two related procedures: one for finding an initial solution to a very large traveling salesman problem (typically 100 or more nodes); the other a way of calculating an absolute lower bound for the optimal tour. The initial solution is obtained by a modification of the "nearest city" approach. Segments of the initial path are chosen from a list of all possible links arranged in increasing magnitudes. Only about 10% of the links are examined to yield disjoint strings of paths. The interconnection of these strings gives a tour which differs from the optimal one generally by a small amount which in turn may be estimated as follows. The possibly shortest route, the "utopian" path, is half the length of the sum of the two shortest links emanating from each node. In many instances the initial solution and the "utopian" path differ by only about 15%. Since this may possibly be within the desired accuracy, some "sufficient solutions" can be obtained by the method presented. If further refinement is indicated, any one of a number of published procedures may be employed. On the other hand if the initial solution and the "utopian" path differ greatly, the initial solution may still be close to the actual optimal path, but this method does not indicate that fact. In those instances where a known solution exists (i.e. Dantzig, Fulkerson and Johnson's 48 city problem) the initial solution is about 5% longer than the optimal tour. The closeness of the "utopian" path and the initial solution depend on the statistical distribution of the nodes to be visited. A limited study of this correlation is presently underway.

WA7.10 Solving the Traveling Salesman Problem by Integer Linear Programming, GLENN T. MARTIN, *C-E-I-R, Inc., 1180 Avenue of the Americas, New York, New York.*

The classical traveling salesman problem—that of finding the shortest itinerary for a salesman who must visit *n* cities and return to the starting point—has tantalized mathematical investigators for decades. A number of methods for finding optimal or near-optimal solutions have been proposed, including ad hoc, probabilistic, dynamic programming, branch and bound, variations of linear programming, and others. At least two (G. B. Dantzig, A. W. Tucker) investigators have proposed models to be solved by Integer Linear Programming; however, no significant investigation of the computational aspects of Dr. Dantzig's model has been reported, whereas Dr. Tucker's model was reported to be (relatively) intractable to available ILP computer codes (1960). In the present instance we report investigation of a different ILP model utilizing the accelerated Euclidean Algorithm—an extention of R. E. Gomory's "Method of Integer Forms." The general model is applicable to both symmetric and non-symmetric systems. For a modest number of cities the model has a great many restraints but a relatively small system is used to initiate computations. Thereafter, any restraints of the total system which are violated are adjoined and computations continued until (1) the system exhibits (ILP) optimality for the explicit system, and (2) all unexpressed restraints are satisfied. The process is finite; nonetheless, its usefulness rests strongly on computational effort associated with practical problems. In the case of the modestly large 42-city problem of Dantzig, Fulkerson and Johnson, nine traveling-salesman restraints and ten integer-cuts were added to an 84-restraint model (861 variables) and a total of 353 iterations were required for solution. Advanced programming may well reduce both final model size and number of iterations significantly, but several present-day computers solve such problems in five to ten minutes. This seems nominal enough. Thus, the approach offers the prospect of (1) efficient solution of relatively large models, and (2) a flexible modeling format to which other restraints may be adjoined. The latter potentiality has not been computationally investigated.

WA7.11 A Branch-Bound Algorithm for Plant Location, M. A. EFROYMSON *and* T. L. RAY, *Esso Research and Engineering Company, Florham Park, New Jersey.*

In its simplest form, plant location can be posed as a transportation problem with no constraint on the amount shipped from any source. However, there is a fixed cost associated with each source (plant). This cost is zero if nothing is shipped from the plant, i.e., the plant is "closed." It is positive and *independent* of the amount shipped if any shipment from the plant takes place, i.e., the plant is "open." Because the fixed charge associated with each plant does not vary linearly with the amount shipped from the plant (there is a discontinuity at zero shipments) this problem cannot be handled using standard linear programming techniques. Various heuristic methods have been developed which are capable of producing "good" solutions to this problem. These techniques are characterized by a high degree of computational efficiency. An algorithm for solving the problem would hopefully be "competitive" from a computational standpoint. This paper describes such an algorithm. The basic contribution is that the problem is formulated as an integer program in such a way that the associated continuous problem can be efficiently optimized. A branch-bound algorithm is then used to solve the problem. The method discussed in the paper has been successfully used to solve practical location problems with upwards of fifty plants.

WP1 Military Operations Research—Where Should it be Done?, (Panel). *Session chaired by* John B. Lathrop, *Lockheed-California Company, Burbank, California.*

Each participant will present a short introductory statement of his views concerning the inherent strengths, weaknesses and proper roles of the various types of organizations carrying out military operations research after which the meeting will be open to discussion. The classical criteria of cost, schedule and performance will be used as a guide. Problems of access to data and skills, financing, maintaining objectivity and communication will be touched upon. The discussion is designed to result in constructive conclusions regarding the proper distribution of military operations research and means for improving its quality, communication and integration into defense decision making.

WP2.1 *California Integrated Transportation Study, W. H. Bender, *North American Aviation Inc., Los Angeles, California, and* C. J. Pounders, *University of Southern California, Los Angeles, California.*

The Systems Engineering approach has been developed by the Aerospace Industries to solve complex problems for the Nation's aerospace and defense agencies. In this paper, a civil application of this approach to the highly complex problem of transportation is described. First, a brief review of California's future transportation problems is presented. California and its transportation networks are then described as systems and the major influencing factors are pointed out. A Transportation Model for the State is then described as a series of integrated computer models: Population, Econometric, Land Usage, Transportation Demand, Transportation Simulation and Evaluation. A discussion of the fundamental assumptions which dictate the sequence of activities is given as well as the model logic and a number of the analytical approaches associated with each of the models. Outputs of the individual models, as well as that of the overall model are then described and major feedback loops defined. Finally, a few specific uses of the model are discussed.

WP2.2 *Transportation Research to Support the Government's New Planning-Programming-Budgeting System, CHARLES J. ZWICK, *Assistant Director, Bureau of the Budget, Washington, D.C.*

The Federal Government has a major impact on our transportation system. Through its Research, Development and Procurement activities the Government plays an important role. The Bureau of Public Roads, the Federal Aviation Agency and the Corps of Engineers are major investors in transportation facilities. Finally, and most importantly, the Government is a major conditioner of the environment in which our transportation system operates through its regulatory and subsidy policies. Clearly, the Government has a pervasive impact on this sector of our economy. The Johnson Administration is in the process of updating policies and procedures in this area so that policy and practice match the technical and economic environment of the '60s. As an aid in carrying out these and other modernizing activities, the President has instituted throughout the Government a new Planning, Programming and Budgeting system. These developments—the deep commitment to updating transportation policy and procedures and the new Planning, Programming and Budgeting system—have produced new requirements for competent research and analysis on the Nation's transportation system. The new requirements for transportation research will be discussed and several potentially high payoff research areas will be detailed.

WP2.3 *Program Design for Integrated Transportation Planning and Development, ROBERT BICKNELL, *Management Technology Inc., Washington, D.C., and D. G. Malcolm, Management Technology Inc., Los Angeles, California.*

Federal programs in development of transportation facilities require comprehensive regional planning prior to individual project approval. Both the Federal Highway Act of 1962 and the Mass Transportation Act of 1964 require the establishment of effective regional planning authorities which will engage in comprehensive, continuous and cooperative planning. Improvement in planning is both an analytical as well as political problem requiring both new planning techniques and new organizations for obtaining political agreement. Research opportunities exist in both the "program design" and "program execution" phases of such comprehensive planning efforts. This paper describes the concept of "program design" applied to transportation planning. The work that has been done in the National Capital Region, mainly during 1965, relating to the preparation of program designs for transportation planning and, later, for comprehensive planning and development of the region, is reviewed. Improvement of planning, both in scope and technique as well as in relation to professional staffing, is discussed. The vital importance of building an adequate communication channel between planners and elected decision makers is stressed. The development of planning, programming, budgeting and action systems for transportation development is discussed, including the unfolding opportunities for operations research, systems analysis, information and analytical system design, and involvement of elected officials as well as the citizens. While dealing specifically with the National Capital Region, the paper stresses similar circumstances and opportunities existing in the majority of metropolitan areas of the world.

WP2.4 *The Development and Validation of a Digital Simulation Model for Design of Freeway Diamond Interchanges, A. V. GAFARIAN, E. HAYES, *and* W. W. MOSHER, JR., *System Development Corporation, Santa Monica, California.*

This paper contains a description of the over-all plan of a digital simulation model for design of freeway diamond interchanges and the work that has been completed to date. The principal goal of the study is to develop a valid general purpose simulation model of a very large class of interchanges, called diamond interchanges, for traffic between a freeway and an arterial street which will enable traffic engineers to study the effect of alternative geometric and control configurations on diamond interchange operations. In order to accomplish this in an efficient manner, the total interchange is segmented into components, one of which is the merging of an on-ramp with the freeway. This paper covers the work performed on the first version of this component. The model, as well as its data reduction program, has been programmed, debugged, and is running. Some of the results obtained with it are included. The paper also contains a discussion of the validation procedures which will be implemented ultimately. Preliminary validation work on the present model has been performed and is described.

WP3.1 *Management Implications of Time-Shared Computing, GEORGE FEENEY, *General Electric Company, 570 Lexington Ave., New York, New York.*

Within the next few years remote-access, time-shared computing will attain widespread availability and use. Many of the characteristics of this mode of computing constitute a revolutionary departure from conventional, batch-oriented processing. These characteristics will be discussed with emphasis on the potential value of remote-access computing to managers and operations analysts and the impact this new capability may have on management practices and operations research methods. Examples will be drawn from 18 months actual experience using time-shared computing in work on a variety of business planning problems, including sales forecasting, risk analysis and budget evaluation.

WP3.2 *Some Experimental Findings in Executive Decision Making Under Uncertainty, PAUL E. GREEN, *University of Pennsylvania, Philadelphia, Pennsylvania.*

A pervasive problem in the design of information systems concerns the behavioral characteristics of managers regarding their acquisition and use of probabilistic information. This paper discusses some highlights of a series of experimental games played by executive and student (control) subjects. The task assigned to the subject was to make a series of information acquisition and terminal act selections under a variety of environmental conditions. Principal objectives of the study were to: (1) Determine subjects' biases for information acquisition and use (as compared to prescriptions implied by statistical decision models); (2) Ascertain the types of behavioral models which subjects employed in deciding how much information to acquire and in utilizing the information in terminal act selection; (3) Investigate intergroup differences as a function of game complexity and decision-making background. The results of the experimental games disclosed some interesting differences between executive and student subjects. Executives displayed lower biases for information, generally, and were able to "live with" greater uncertainty. Analyses of the fine structure of the games revealed a variety of behavioral models, including "mixed" models (e.g., Bayesian—minimax regret). A particularly interesting finding concerns the significant changes that occur in behavioral characteristics when environmental conditions undergo only slight modification.

WP3.3 *Managers are Human: Research on the Management Process, MICHAEL I. HALBERT, *Marketing Science Institute, Philadelphia 4, Pennsylvania.*

Managers and researchers often speak English when they talk to each other, but their languages often contain different ideas about reality. Words like problem, evidence, solution, proof and usefulness have different referrents. The manager thinks he needs more facts: the researcher thinks he needs more theory. The manager often requires only a feasible solution; the researcher may be concerned with optimal choice from a set of alternatives. The manager may overvalue intuition; the researcher may undervalue it. If operations research is to develop useful methods of understanding and solving management problems, it must know what managers are like and what their problems are like, not as a source of heuristic models, but as human, complicated phenomena. Research of the management process requires as much sophistication as mathematics. Studying people as people is different from studying people as data generators or parameter setters In many cases the basic research tool is another human—the researcher himself And to use this tool he must know how it works. The only researcher who can adequately study managers and the management process is an open, mature, nondefensive, perceptive researcher.

WP3.4 *Financial Control of Research and Development, EDGAR A. PESSEMIER, *Purdue University, Lafayette, Indiana.*

Financial control of research and development occurs at two distinct levels. At the first level, decisions are made concerning the acquisition, maintenance and general direction of personnel and facilities with specific research capabilities. Second level decisions concern the acceptability of proposals produced by the research function. In one case, funds are allocated to search and, in the other, to the development and introduction of new products or processes. The financial aspects of acquiring research capabilities and directing the search for new scientific, technical and commercial knowledge have not been explored in a manner which yields ready guidance to primary decision makers. A computer simulation model, which processes estimates concerning standard technical and economic variables, has been constructed and tested. It yields measures of cash flows, return, and risk, which are suitable for selecting an optimal policy and the related capital budget. Sensitivity analysis has been conducted to measure the degree to which selected estimating errors and nonoptimal policy decisions affect the overall return from a research and development program.

WP3.5 *Decision Critical Path Method: A Method for Simultaneous Planning, Scheduling, and Control of Projects, GERALD L. THOMPSON, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania, and* WALLACE CROWSTON, *School of Industrial Management, Massachusetts Institute of Technology, Cambridge, Massachusetts.*

The critical path method has been suggested as a suitable scheduling technique for development projects. In the planning phase of such an approach, a project graph is constructed, which lists the jobs to be done as well as their technological ordering. Implicit in this process is a series of decisions on the best method of performing the necessary jobs in the project. The paper shows that it is not possible, in general, to make these decisions optimally without the use of scheduling information. It is shown that managers must solve the planning and scheduling problems simultaneously. A decision project graph is defined, which includes information and alternative methods (when they exist) of performing each job, the time and cost of the alternative, and the interdependencies among alternatives, as well as the usual technological ordering. Integer programming and heuristic solution techniques are developed for the joint problem represented by the decision project graph. Finally, implications of the approach for project planning, scheduling and control are discussed.

W4P.1 *The Use of a Computer Aid in Manned Space Station Experimental and Operational Planning, R. E. MINK, *IBM Federal Systems Division, Space Guidance West, 9045 Lincoln Blvd., Los Angeles, California.*

Considerations on the application of the IBM scheduling and resource allocation computer program (EXOTIC II) to manned space station experiment and operational planning are presented. The data base includes information from the NASA Headquarters Orbiting Research Laboratory study performed by IBM. Implications as to criteria for performing the computer aided planning are discussed. Conclusions as to man/machine interface requirements and the procedures for online manned spaceflight planning system utilization are given. Data which supports the criteria identified for the EXOTIC program application are shown in the form of sample schedules and resource allocation summaries. These summaries include time-line schedules for crew members, data handling demands and power system loadings. Additionally, summary data plots across time of the activity schedules and ground target and support station availabilities as a function of orbit are presented. Other summary data such as support equipment usage tables, crew assignments statistics, crew assignment histories and payload summaries are included.

WP4.2 *A Mission Scheduling System for Manned Space Flight, R. F. KLAWA, *General Dynamics/Convair, San Diego, California.*

Increasing mission durations as well as the number and complexity of interfaces between experiment, mission tasks, crew, spacecraft systems and ground systems, are the new characteristics of manned space flight. To cope with the problem of scheduling these functions, a new tool has been developed. This tool or technology is composed of a series of computer programs. The characteristic features of the scheduling system include dynamic priorities for each task, a look-ahead or anticipation capability, using an asynchronous adaptive time base. The scheduling system described has successfully generated schedules and displays of mission time-lines and resource expenditures. Development of the basic techniques has occurred over the past four years with specific application to mission scheduling during the past year.

WP4.3 *Closing the Planning-Scheduling-Allocation Loop, FRANK B. KAPPER, *The MITRE Corporation, Bedford, Massachusetts.*

This paper presents both a general context for planning, scheduling, and resource allocation for manned-space flights; and an algorithm for feasible resource management. The conceptual framework discussed provides a vehicle for achieving a deeper understanding and better appreciation of the subtle process/product relations in mission planning. Automated and highly flexible planning, scheduling and resource allocation (P/S/A) capabilities are considered indispensable in the attainment of more complex space objectives. The paper also describes in specific detail a computer-oriented method which permits practical resource management in a real time, on-line environment.

WP4.4 *Flight Operations Planning for Manned Spaceflights, (Panel). *Session chaired by* MICHAEL W. LODATO, *The MITRE Corporation, Bedford, Massachusetts.*

The three invited papers that will precede the panel are concerned with Flight Operations Planning (FOP) techniques that are in the form of computer programs and which treat only specific aspects of the overall FOP problem. The panel will use this as a jumping off point to a more comprehensive discussion. The goal of the panel is to focus attention on two general problems: (1) that of generation flight plans for manned space missions which are free of pre-execution conflicts and (2) that of providing a capability to re-generate flight plans (in real-time) during the course of a mission. OR techniques that will aid in the determination and implementation of a methodology in which these two problems can be solved on a continuing basis will be discussed.

WP5.1 *Optimal Stopping, MORRIS H. DEGROOT, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

Suppose that observations $X_1, X_2, \cdots$ can be taken sequentially from a given population whose distribution is, at least in part, unknown. Suppose that there is a given cost per observation and that after each observation X_n the experimenter can either stop sampling and receive a specified reward or continue sampling and observe X_{n+1}. In some problems the experimenter's reward when he stops sampling is X_n, the value of the last observation that was taken; in other problems his reward is $\max(X_1,\cdots,X_n)$, the largest of the observations that were taken. The total gain of the experimenter is the reward he receives minus the sampling cost. The problem is to find a stopping rule that maximizes his expected total gain. Solutions of these problems are derived for various special distributions of the observations. The Bayesian approach is followed and unknown parameters are taken to have natural conjugate prior distributions. Variations and generalizations involving discounted observations, forced stopping, and more than one population are also considered.

WP5.2 *Estimation of Parameters in Reliability Models, BENJAMIN EPSTEIN, *768 Garland Drive, Palo Alto, California.*

Estimation of parameters in reliability models is usually based on data in which there has been some degree of censoring. In this paper some methods of making point and interval estimation are discussed, which are in some degree best for various types of censored situations.

WP5.3 *Gambling for Survival, ALAN TRUELOVE, *C-E-I-R, Inc., Beverly Hills, California.*

What is the optimal gambling policy in a favorable game, under a fixed cost-of-living charge (or minimum bet situation) where the object is to minimize the probability of ruin? The situation could conceivably have practical applications as follows: (i) A company with a small amount of capital must decide on its product lines for the next year, from a variety of possibilities with different risks and set-up (investment) costs. What is the optimal policy to follow so as to maximize the chance of surviving, not just this year, but infinitely? The "cost-of-living" charge could be the irreducible minimum of its expenses. (ii) The same problem, with an investor facing a daily choice of investment possibilities. The "cost-of-living" is his personal income requirements. While these problems have not been solved, the following results have been obtained for a simple "steady-state" situation: The optimal betting policy depends *only* on the current amount of resources, and the current odds being offered. For large resources, the optimal bet is asymptotically a constant, independent of the resources (but still depending on the odds being offered). Thus a millionaire should stake on an even bet, where the true probability of winning is $2/3$ and the cost-of-living charge (or table fee) is \$1, precisely \$5.89, if his only desire is to avoid ruin.

WP5.4 *Optimum Sequential Procedures for Calibrating Complex Engineering Systems, STEVE WEBB, *Rocketdyne, Canoga Park, California.*

Problems to which this work is directed may be typified by the following, which motivated the study. The oxidizer and fuel flowrates for small attitude-control rocket engines must be adjusted within a small number of test firings. The flowrates are random variables whose mean values are determined by a nonlinear function of orifice diameters, subject to adjustment during the calibration tests, and several unknown parameters which characterize the system. The engine-calibration problem is an example of a wide class of problems which may be treated by the methods developed. In general, a response vector Y is given by an expression of the form $Y=f(X, \beta, e)$, where X is a vector of controllable independent variables, β is a vector of unknown parameters, and e is a random error component. It is assumed that a sequence of n values for the vector X must be chosen sequentially so that after the nth test the probability is maximized of the next observation vector falling within a prespecified region. Specific problems of interest are determination of the setting (X value) for the ($n+1$)st test, computation of the probability of calibration as a function of n, estimation of the parameter vector, and determination of the strategy to use in selecting the first n values of X.

WP5.5* Statistical Analysis of Scientific and Technical Information Needs, ARNOLD GOODMAN, *Space and Information Systems Division, North American Aviation, Downey, California.*

The Department of Defense User Needs Study recently surveyed the scientific and technical information needs of engineers and scientists in the defense industry. It asked questions about the user (e.g., management responsibility, occupation, education, experience, and age), his tasks (e.g., type, size, input and output), his needs (e.g., type, importance, and satisfaction) and the associated information flow. Appropriate ordering and scaling of the qualitative responses to the questions lead to a more thorough analysis than that provided by the mere enumeration of the responses in each question category. This paper discusses ordering, scaling and other aspects of the survey's statistical analysis.

WP6.1* Surge Capability of an Air Logistic System, ALFRED G. ASWAL, *Douglas Aircraft Company, Long Beach, California.*

An air logistic system's total surge capability (ability to move cargo during wartime) is limited by two major parameters, the number of air transports available and the number of personnel available to fly and maintain the system. For a given amount of resources the question arises of how one determines the number of men and air transports that one should maintain during peacetime so as to be able to maximize the effectiveness of the system during wartime. This paper examines the question from a cost-effectiveness viewpoint.

WP6.2* Selection of Subsystems, Equipment and Performance for Optimum Weapon System Configuration, JACK REBMAN, *Lockheed-California Company, Van Nuys, California.*

Requirements of current contract definition phase program call for optimization of the weapon system configuration. From an array of possible subsystems, equipment and performance characteristics, it is necessary to choose that complement which is optimum. The variety of items under consideration is typified, for example, by speed of the vehicle, crash-worthiness measures, weapons, armor, avionics, cockpit configurations, etc. In this paper selection methods are described which were used during CDP for the Army's AAFSS weapon system. The general methodology provides a consistent logic and a set of decision parameters for optimal selection from among widely different candidate items. A general effectiveness model is presented which integrates pertinent performance parameters. With appropriate detail submodel, individual or groups of candidate items can be evaluated. Costs are treated in a similar way. Candidates are examined as incremental changes in configuration. To be acceptable an overall program saving must result from the incremental change and the threshold payoff ratio must be exceeded. That is, the candidate should realize a profit and the return on investment should be greater than a pre-selected value. Examples are presented to illustrate applications to subsystems, individual pieces of equipment and performance parameters.

WP6.3* Cost Effectiveness Fallacies and Misconceptions Revisited, A. D. Kazanowski, *North American Aviation, Downey, California.*

The rapidly expanding utilization of cost effectiveness by industry, as well as local, state, and federal government raises the threat of repetition of acknowledged errors and fallacious analyses. Experience, and reviews of numerous analyses, indicate that the intuitive plausibility of cost effectiveness often gives rise to the commission of subtle (and some not so subtle) errors. The conduct of valid analyses is an art that requires a profound understanding of potential pitfalls. By emphasizing in this paper, some of the past fallacies and errors, it is hoped that their commission may be precluded and thus more valid analyses result. This paper expands upon an earlier effort along similar lines. Almost two dozen different types of fallacies and misconceptions have been compiled and will be included in this paper.

WP6.4* On Criteria and a Selection Process, W. A. Dwyer, *The Boeing Company, Seattle, Washington.*

We are concerned with the decision situation where only one, say A_i, of a set of n concepts, configurations or systems is to be selected for further development. It is assumed that this is a nontrivial decision situation—that there is no A_i which is unambiguously superior to all others, and all "hopeless" concepts have been thrown out. In effect, we are also excluding those rare, if not academic, situations where a single, simple (not composite) measure of effectiveness is taken as adequate for decision. As a pure problem this is somewhat academic since presumably at least one more design iteration is in the works. While this does not really alter the original problem, it does bear on the approach to the decision aids. Even a small matrix of A_i and x_i (where the x_i's are criteria values, with or without formally associated weights) presents a formidable number of potential situations for consideration by the decision maker. A procedure similar to some algorithmic approaches employed in optimizing redundancy is suggested and outlined. However, the results of a study of criteria associated with a launch system analysis are cited as a caution and an illustration of an unanticipated failure of an attempt to enhance certain criteria in a design process. Possible explanations and implications of the findings are presented.

WP6.5 Cost-Effectiveness of Current vs. Future Aircraft Runway Performance, Karl Seiler, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

The purpose of this paper is to develop an algorithm to examine the tradeoffs of aircraft runway performance versus cost versus time of availability. Consider three hypothetical aircraft within three operational time frames: A_t (earliest), A_{t+1} (one year later), and A_{t+2} (two years later). Assume that an array of the variables of cost, performance and time of availability reveals that no single aircraft has the ideal combination of lowest cost, best performance and current availability. Decisions confronted with such dilemmas may be clarified by various tradeoff techniques. A description of such a technique is presented fully realizing that the final choice will perforce require the introduction of judgment.

WP6.6 Some Issues in Conducting Military Cost-Effectiveness Studies, Peter D. Fox *and* Dan G. Haney, *Stanford Research Institute, Menlo Park, California.*

A framework for conducting military cost-effectiveness analysis is presented, taken from Fox (*Opns. Res.*, **13**, 191–201 (1965)). The article argues that the function of the analyst who performs cost-effectiveness studies is usually to present to the decision-maker a range of alternative systems rather than to recommend the selection of a particular alternative.

The use of cost-effectiveness analysis as a tool for systems design as well as for systems evaluation is discussed. The necessity of meaningful measures of effectiveness that are related to broadly defined systems goals is indicated. Particular emphasis is devoted to measures of effectiveness that appear not to lend themselves to measurement. Several alternative approaches are offered to evaluate systems where effectiveness cannot be quantified in a meaningful fashion, including the use of scenarios and real-time simulation. Some of the implications of treating multiple measures of effectiveness by attaching numerical weights to the measures are discussed.

WP7.1* Operations Analysis of American Education at the U.S. Office of Education, Alexander M. Mood, *Office of Education, Department of Health, Education, and Welfare, Washington, D.C.*

The paper will describe the current status of several operations analysis studies being pursued at the U.S. Office of Education. The more important models under construction are: a pupil flow model to describe the dynamics of the progress and branching of pupils in the educational system, a teacher flow model to describe the dynamics of the composition of the educational staff, a quality of education model to relate educational achievement to factors considered for educators to be important to learning, a cost analysis study to estimate the per pupil cost of various education processes, an occupational requirements model to explore the relationships between educational output and the needs of the economy.

WP7.2 Computer Evaluation of the Diagnostic Decision Process in Disability Determination, Sylvan Hack *and* Saul D. Hearn, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.*

The area of interest is the decision process with regard to the allowance or denial of a disability claim based on submitted evidence. This evidence consists of several broad classes, primarily medical with some non-medical, and totalling approximately 100 items of information. Based on the data provided by a sample of these reports, the problem is the degree to which automation can be used to achieve greater consistency in the decision process. The initial plan of attack makes use of a step-wise multiple regression analysis. This analysis furnishes information as to the importance of each category or question along with an indication as to its degree of reliability. The derived values also give a comparison of actual and predicted actions when applied to historical data. Further analyses such as rank order correlation and profile testing are used to supplement the regression method.

WP7.3 Hospital Patient Through-Put Analysis, MIKE KOTTLER, *3592 Severn, Cleveland Heights, Ohio, and* HAROLD NISSLEY, *2925 Euclid, Cleveland, Ohio.*

The allocation of hospital facilities: doctors, therapists, beds, operating rooms, etc. to an overflowing demand of patients with various complaints can be efficiently studied by a joint linear programming and queuing theory approach. The progress of patients in various degrees of disability is examined using non-parametric statistical techniques to estimate parameters such as mean waiting time (time between application for admission and admission to the hospital) and mean service time (the mean time required for the patient to go from one diagnosis state to the next higher diagnosis state). Use of various aspects of these parameters is made in the study of the following questions: 1) From which state should a patient be admitted in order to optimally utilize hospital facilities? 2) What is the expected time this patient will spend in the hospital? 3) What is the expected cost to the hospital of this patient? 4) How do the above answers compare with the current method of admitting patients?

WP7.4 Implementation—An Application of the Literature to a Study of Decision Making in a Public Health Agency, DAVID H. STIMSON, *University of California, Berkeley, California.*

This paper deals with the problem of implementation of the results of research, a topic discussed with increasing frequency in the operations research field. First, the scope of the implementation literature is indicated by references to work in such diverse areas as rural and medical sociology, political science, management science, human relations, group dynamics, innovation in industry and history of science. Then a brief summary of the main points found in this literature is presented under three headings: (1) the process of change, (2) the techniques of change, and (3) the reasons given by consultants to clients in support of proposed changes. Finally, these findings are applied to a case history of an organizational study centered on a public health agency's decision making and resource allocation procedures. The agency's response to the recommendations contained in the study is analyzed in terms of significant points taken from the above literature.

WP7.5 Programming a Plan for a Job Corps Training Center, HARRY A. GRACE, *University of Southern California, Los Angeles, California.*

Social psychological theory may be as readily applied to solving puzzles as it has already been applied to problem-solving. Whereas in problem-solving we apply means, such as behavioral scientific methods and procedures, to test ends from time to time; to solve puzzles we proceed backward from stated ends and test the efficacy of our means, i.e. techniques, institutions, channels of communication and so forth, from time to time. Both problem-solving and puzzle-solving are empirical, neither proceeds nor succeeds on face or faith validity. A major effect of applying social psychological theory to programming solutions to puzzles is that in so doing we reduce the aura of magic and superstition which customarily surround and occasionally smother operational solutions to practical challenges. In the poverty programs, especially, we are asked to make the means to jobs explicit to the poor and this implies that the social psychologist must first operationalize those dimensions of training which are relevant to the criteria of job-entry, job-success, and promotability-from-the-job. Programming a plan for a job corps training center is one case in point of this operational approach to the design of a social system.

WP7.6 War Gaming the War on Poverty, THOMAS A. GOLDMAN, *Philco Corporation, 515 Pennsylvania Ave., Fort Washington, Pennsylvania.*

A computer simulation is being developed for the comparison and evaluation of alternative strategies in the War on Poverty, specifically, the Community Action Programs under the Office of Economic Opportunity. The application of simulation techniques to relatively large socio-economic aggregates, such as an entire city, is comparatively new, especially at the level of detail required in this case. In order to achieve the objectives of this simulation effort, it is necessary to represent explicitly the distribution of all the relevant demographic and other attributes of the community and its inhabitants, as well as the functional relationships connecting these attributes and their change over time. This paper describes the approach adopted and techniques employed to achieve the indicated objective and discusses some of the implications for national policy with respect to the elimination of poverty.

WP7.7 The Use of Mathematical Programming in Water Quality Management, ROLF A. DEININGER, *University of Michigan, Ann Arbor, Michigan.*

This paper is concerned with the derivation of mathematical models to determine optimal pollution control systems for an entire river shed. Several mathematical models are formulated with the objective of maintaining the desired river water quality at minimum cost. Parameters of river water quality considered are the bio-chemical oxygen demand, the dissolved oxygen and the bacterial water quality. The models formulated lead to linear programming, nonlinear programming, mixed integer and stochastic programming problems. Specially developed computer programs are discussed.

WP7.8 Management Development and Productivity in Underdeveloped Nations, HAROLD W. MARTIN, *Rensselaer Polytechnic Institute, Troy, New York.*

The relationships between the effectiveness of both macro-Management and micro-Management and the rate of economic growth in underdeveloped nations and in their constituent economic subsystems are examined in terms of systems productivity or degree of satisfaction of the primary and secondary objectives of such systems. Management problems intrinsic to elementary developing economies are discussed and their relationships to effective Management decision making regarding investment and generation of developmental capital funds are analyzed. Experiments in Management development and productivity improvement in Israel and West Africa are described and experimental results therefrom are presented.

WP7.9 Simulation of Shelter Systems in a Contaminated Environment, JACK C. ROGERS, *Booz, Allen Applied Research, Inc., Los Angeles, California.*

Extensive simulations have been devloped to describe the operation of collective protection shelters in a biological or chemical contaminated environment. These simulations include the detailed description of (1) the contamination challenge to the shelter and personnel as a function of time; (2) operations of personnel in the contaminated environment, such as donning masks and protective clothing, moving to the shelter through the contamination field, entering the airlock of the shelter, removing the protective clothing and decontaminating, and entering and leaving the shelter proper; (3) operation of the shelter components and the shelter as a system; and (4) interaction of the shelter and men within the shelter. The output describes the buildup of the concentrations of contaminant in each room of the shelter as a function of time and the effect of the contaminant on the personnel. Possible applications to non-military problems are mentioned.

WP7.10 Operations Research Models and Computer Applications in Food Service Management, JOSEPH L. BALINTY, *Tulane University, New Orleans, Louisiana.*

The principles and operational techniques of scientific management have been made available recently for the multimillion dollar food service industry. Careful analysis has shown that the criterion of optimizing activities in volume feeding operations depends primarily on the menu plan. Menu planning has been identified as a mathematical programming problem solvable in general by the decomposition principle of linear programming. Particular aspects of the problem may require programming with upper bounds, variable coefficients, integer programming and stochastic integer programming solutions. Forecasting, purchasing and inventory control models are needed to feed information into the menu planning program and scheduling models, or job shop simulation may be applied to program food production. The use of computers and especially the availability of on-line computer service make the application of these models feasible for food service organizations of any type with a potential food cost saving of 20 per cent or more. Methods of central computerized menu planning are being successfully tested in hospitals with the programs applicable to the vast area of military, school, detention- and nursing homes feeding problems. Further success and extension of the models depend largely upon the re-education process of the food service personnel.

TA1.1 *A Common Approach to Aircraft and Aircrew Scheduling, J. TAYLOR, *B.O.A.C., Pennine, Terry's Lane, Cookham, Maidenhead, Berks, England.*

In certain circumstances it is possible to express the outcome of aircraft and aircrew scheduling exercises in the form of sequences *A–a–c–f–j——B* where the end terms signify two special events and the inner terms other events which must be carried out in due sequence. For example, in the case of aircraft, the sequence may be interpreted as the event of an aircraft coming off maintenance, operating a succession of flights from a central base and eventually becoming ready for maintenance at an appropriate time. In the case of aircrew the two end events signify departure from and arrival at the crew base, the intermediate events now signifying successive sectors flown. Both contexts give rise to large scale combinatorial problems, the solution of which by linear programming techniques can be time consuming. This paper discusses heuristic methods which appear to meet practical requirements and which have several in-built optimizing features. Significant use is made of the several constraints applicable in the two contexts.

TA1.2 * Understanding About OR: A Need for Decision-Making, C. DEETMAN, *KLM Royal Dutch Airlines, Schlipol Airport, Amsterdam, SPLI/BG, The Netherlands.*

The success of Operations Research depends a great deal on the understanding of what OR can do. There are, however, problems on how to tell the story to the top and how to educate people to break through the barrier of misunderstanding on this subject. An illustration is given out of practice whereby Operations Research had to be implemented into an airline organization. All problems come down to the sensitivities of the human being. Information, Psychology, and Patience are the tools for a good atmosphere to build the cockpit of management, where people can work with the information to perform their controlling task.

TA1.3 * Commercial Airplane Market Analysis by Airline Simulation, LEE R. HOWARD, *Lockheed-California Company, Burbank, California.*

The determination of markets for commercial transport airplanes is keyed to the manner in which airplanes can be used most profitably by the airlines. Lockheed has developed an economic model which simulates airline operations for this purpose. The model considers traffic forecasts, airplane prices, performance and operating costs, revenue yields, passenger preference related to fare levels, flight frequency and trip times, and a level of operation and airplane mix consistent with the factors of competition and Government regulation. In addition to determining airplane markets, the model may be called upon to determine economics achieved by different fleet compositions, system sensitivity to adjustment of input variables, and to assist in year-by-year financial planning for manufacture, acquisition, and operation of flight equipment, and development of airline schedule plans. This paper briefly discusses the methodology and presents some of the results from applications in supersonic transport market analysis.

TA2.1 * Bureau of the Budget Objectives and Plans in Cost-Effectiveness Analysis, HENRY ROWEN, *Assistant Director, Bureau of the Budget, Washington 25, D.C.*

The Bureau of the Budget has become the focus for a greatly expanded emphasis on program budgeting and cost-effectiveness analysis throughout the Federal Government. In this paper the problems in bringing about these developments are examined and the relationship of the Bureau of the Budget to the operating government agencies explored. The objectives of the Budget Bureau in introducing the new Planning-Programming-Budgeting System are identified and the nature of its continuing relationship with the departments examined. The areas that most need research and support by the operations research community are identified.

TA2.2 * Cost-Effectiveness Analysis at the State Level, LESLIE E. CARBERT, State Planning Officer, *11th and L Building, Sacramento, California.*

The unique problems of conducting and implementing cost-effectiveness studies at the State level are discussed. Particular problems under state jurisdiction most amenable to cost-effectiveness analysis are identified. The California experience in contracting with aerospace corporations for feasibility studies in this area are reviewed and possible extensions of these efforts are identified.

TA2.3 * Cost Effectiveness of Controlling Land Inputs, HOWARD HJORT (AND STAFF), *Office of the Secretary, U.S. Department of Agriculture, Washington 25, D.C.*

In the 1950's, farm price support programs were supplemented by programs for taking land out of production. Farms and even fields vary as to their productivity (yields) and the farmers' willingness to participate varies even within yield categories because of variations in their economic and social environment. The question is then: What is the optimum (least cost to government) combination of rates relative to (1) productivity of land and (2) premium rates paid for alternative levels of participation by individual farmers, that will provide in the aggregate certain specified levels of output reduction? To evaluate the effectiveness of alternative rate schedules, it is necessary to have information concerning (1) the per cent of participation for each land productivity class associated with alternative rate structures, and (2) an estimate of the output reduction associated with each level of program participation. In 1966 an experiment is to be conducted with respect to one land rental program (the Cropland Conversion Program). This experiment involves the use of alternative rate structure in different but similar counties. Data on participation, program costs and output reduction will be obtained for each rate structure. More extensive experimentation would be desirable, and is outlined, for other land retirement programs of the Department. Careful experimental design can increase information for evaluation of alternative programs and rate schedules within programs without greatly decreasing the effectiveness of the current programs or increasing their costs. Through actual results of such experimentation, it is expected that uncertainty about program consequences could be reduced, more accurate budget estimates could be made, and more cost-effective rate schedules (programs) could be designed resulting in less total cost to taxpayers or more income for farmers.

TA2.4 * Systems Analysis in the War on Poverty, ROBERT A. LEVINE, *Office of Economic Opportunity, Washington 25, D.C.*

A discussion of the application of systems analysis to comprehensive planning of civilian programs. The Office of Research, Plans, Programs, and Evaluation of OEO prepared a comprehensive plan for War on Poverty programs beginning in Fiscal Year 1967. This was the first such plan done for a civilian program, and the paper discusses differences between civilian and defense applications of Systems Analysis, as well as some general principles and limitations of such analysis, with examples drawn from the process which culminated in the 1967 anti-poverty plan.

TA3.1 *Problems of Large Hospital Administration, VERNON L. NICKEL, *Rancho Los Amigos Hospital, 7601 East Imperial Highway, Downey, California.*

The problems of administering a large hospital are common to those involved in the operation of all large systems, together with a number of difficulties peculiar to hospitals. These will be discussed and illustrated with reference to Rancho Los Amigos Hospital.

TA3.2 *Simulation of a Psychiatric Out-patient Clinic, COLIN SHANKS, *Department of Electrical Engineering, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.*

A number of models of the operation of a psychiatric out-patient clinic have been constructed. The difficulties involved in the formulation and analysis of these models will be discussed.

TA3.3 *Simulation of the Initial Psychiatric Interview, DR. LARRY BRODY, *Los Angeles County General Hospital, 1200 North State Street, Los Angeles, California.*

The initial psychiatric interview is interpreted to be a multistage decision process of adaptive type. Using the conceptual structure of dynamic programming, simulations of this process have been constructed which are useful for both training and theoretical purposes.

TA4.1 *OR Applied to Advertising in Depth, RUSSELL L. ACKOFF, *University of Pennsylvania, Philadelphia, Pennsylvania.*

The theoretical and practical output of a series of interrelated studies of advertising is presented. The aspects of advertising covered include the amount spent, its allocation to markets, media mix, the timing of messages, and message content.

TA4.2 *Simulation of a U.S. Navy Public Works Organization, JOHN D. TOELLNER, *and* JOHN B. HOWENSTINE, *Ernst & Ernst, 615 South Flower St., Los Angeles, California.*

Public Works maintenance can be performed by decentralized shops at each Naval facility within a geographical region or by one centralized set of shops or by any consolidation of a set of shops, when they are interested in the financial saving that would result. However, if the saving were accompanied by an unsatisfactory increase in the waiting time of work to be done, then the decision may be to not consolidate. To make the consolidation decision, both the savings and the order waiting time must be known. To facilitate the comparison of alternative organizational forms, we have adopted the criteria of standardizing the order waiting time for each alternative and determining the staff required to produce that waiting time and from the staff level determining the cost. The cost of each alternative organization is compared to a base case to determine the cost savings (if any). To provide the needed information, a computer simulation was created. The program starts with the determination of waiting times and the operating cost of a base case. Each subsequent alternative organization is presented to the model as an independent case. The model solves for the staff level to provide the base case waiting time. This staff level, in turn, generates the overhead structure and then the operating cost is determined. There is no limit on the number of alternatives that can be examined. The model is designed to be used on a wide variety of types of installations.

TA4.3 * Operational Research in Educational Planning: An Experimental Project by the O.E.C.D., *authored by The Educational Investment and Development Division, Organisation for Economic Co-Operation and Development, 2, rue Andre-Pascal, Paris 16ᵉ, France.*

Preliminary results of three current O.E.C.D. projects exploring the application and development of operations research techniques for educational planning and administration are described. A brief summary of O.E.C.D. work in educational planning emphasizes the use and development of the manpower forecasting techniques in the establishment of educational targets. Problems involved in implementing long-term educational plans indicate the desirability of an operational study of the educational system as a necessary step in further programming and implementation. Previous work in operations research in educational planning is surveyed. Special attention is paid to mathematical model building for educational planning—a field where O.E.C.D. has played a pioneering role. The possibilities of using current industrial and military techniques are discussed. Considered among others are warehouse location methods for school location, PERT-CPM as a method of programming long range educational plans, and decision-making, information flow and other communications models as a means of improving both administrative and classroom efficiency. The current development of specifically educational models and methods is outlined. Finally, preliminary results of O.E.C.D. studies in some Member countries are indicated. These studies attempt to determine areas in which operations research is likely to be most helpful.

TA5.1 * An Integrated Approach to Logistics Analysis, C. B. MOORE, *Fort Worth Division of General Dynamics, Fort Worth, Texas.*

In recent years, the need for improved logistics planning has been growing at an accelerated rate. Increased weapon system complexity, expanded operational requirements, multiple operational uses, higher utilization rates, and the requirement for the best defense for the dollar from the standpoint of cost-effectiveness—all have contributed to the need for logistics planning in every phase of a weapon system program. Concurrent with the growth of logistics and the increased demand for logistics planning, it has been necessary to develop improved methods, techniques, and procedures for use in the analysis of logistics problems. This paper deals with an integrated set of mathematical models and their use in logistics decision-making and program planning at all levels and in all phases of a weapon system program—conceptual, contractor definition, acquisition, and operational. Specific topics covered include the following: logistics elements and their interrelationships; the need for logistics models; requirements for model flexibility, versatility, and usability; the necessity for an integrated analysis approach; and typical applications of the approach. Emphasis has been placed on specific problem areas, future areas of application, and the expanding role of Operations Research in logistics analysis.

TA5.2 An Application of Linear Programming to Strategic Deployment Problems, George R. Fitzpatrick *and* Justin C. Whiton, *Research Analysis Corporation, McLean, Virginia.*

Most studies of strategic deployment have focused on contingency requirements in one part of the world or another. In some instances, the so-called "worst case" has been postulated on the questionable premise that the capability to meet that requirement embraces all others. This paper describes a linear programming model that permits consideration simultaneously of an entire set of contingency requirements around the globe. The model can solve quickly, under a broad spectrum of assumptions, for the least-cost mixes of deployment means (airlift, sealift, and prepositioning ashore or afloat) capable of meeting specified requirements. The model was developed by the Research Analysis Corporation as part of the U.S. Army's study program and has been used in analyses of deployment systems conducted in support of Joint Chiefs of Staff and Office of the Secretary of Defense. Results of analyses have influenced the preparation of long-range plans as well as the formulation of the Fiscal Year 1967 Department of Defense budget. The paper describes the structure of the model and the nature of inputs required. Emphasis is placed on the utility of the model as an analytical tool for testing the sensitivity of the assumptions and other inputs, determining the marginal values of increments of available deployment systems, and for conducting other analyses. Representative results are discussed.

TA5.3 Impact of Air Mobile Operations on Logistics Concepts: A Preliminary Look, Ray M. Clarke, *Research Analysis Corporation, McLean, Virginia.*

The paper discusses some of the problems generated in achieving adequate logistics support of the new Army Airmobile Division, with primary emphasis on the supply aspects. Support of widely dispersed and ever moving combat units requires a reappraisal of current procedures to insure true air mobility. Possible changes in existing practices are discussed employing some of the latest techniques available for supply control and distribution tailored for use in an operating environment such as Viet Nam. Discussion includes new approaches in packaging, air delivery to and within an airmobile division area, and means of reducing the burden of supply record keeping and requisitioning on combat organizations. The objectives of the proposals are to create a supply system that is, (a) responsive to the needs of combat units in today's environment, (b) develop confidence of the user in the effectiveness of the system, and (c) insure that airmobile combat units are not restricted unduly by a "logistical tail."

TA5.4 Computer-Assisted Testing and Analysis of Logistics, Thomas B. Roelogs, *Research Analysis Corporation, McLean, Virginia.*

This paper summarizes the application of a man-computer system to a current Army problem. The system is operated under the acronym SIGMALOG and was developed for use in gaming or simulating the military logistics aspects of theaters of operations. SIGMALOG incorporates a set of computer models for simulation of theater logistics through a series of time periods. In their primary use, models are employed within a methodological framework incorporating manual analysis of computer runs, leading to decisions and preparation of input data for succeeding models within a time period or to initiate succeeding time periods. An option is available to sequence each model in turn through all time periods. The primary use of the models can be addressed to a wide variety of problems including examination of: alternative operational concepts; the effect of logistic support on combat; and, the ability of the Continental U.S. to support postulated overseas operations. At the present state of development, SIGMALOG includes computer simulations of logistics in the following areas: manpower control; materiel consumption, stock levels, and movements; casualty generation and hospitalization; and transportation of forces and supplies. For purposes of military analysis and computational convenience, the theater is divided into geographical subdivisions, i.e., regions. The models treat the logistic activities in each region and time period to determine workloads to be accomplished in quantitative terms. These workloads are subsequently converted into troop unit equivalents. Typical workloads quantified are replacements to be processed, troop units to be deployed, materiel consumed, supplies to be received/stored/issued, patients to be treated, equipment to be maintained, and facilities to be provided. The models are described in this paper as they were applied to a recent Army study of the feasibility of an existing theater operational plan.

TA5.5 Decision Theoretic Analysis of Headquarters Logistical Command and Control Systems, S. P. Todd, Jr., *Dunlap and Associates, Inc., 1050 31st St., N.W., Washington, D.C.*

In spite of large Department of Defense expenditures for Command and Control systems, only isolated studies have dealt with quantitative analysis of these systems. Thus, a comprehensive framework for the development of a quantitative Command and Control Science does not yet exist. This paper presents the results of a study of the applicability of statistical decision theory to the development of a Command and Control system design methodology. The paper explores the application of statistical decision theory to a specific class of Command and Control Systems: Resource Management Systems. The research consists of (1) the development of a model of resource management systems, and (2) the application of statistical decision theory to the problem of evaluating system characteristics with respect to three types of problems: selection of an appropriate level of investment in a Resource Management System, allocation of a portion of the investment to an information system, and utilization of the information system to make optimum military resource allocations. The problem of measuring system performance in terms of the achievement of military objectives is discussed. Application of the model and the techniques developed are demonstrated by example problems.

TA5.6 A Computerized System For Forecasting Wartime Replacement Requirements, MARTIN W. BROSSMAN, JOEL MORRIS, *and* VINCENT SARDELLA, *Research Analysis Corp., McLean, Virginia.*

This system is designed to utilize previously generated war games and computer simulations to develop loss rates under various military postures and activities. These loss rates when applied by the system models against approved war plans, will provide a quantitative time-phased forecast of replacement requirements by item. The system accounts for losses incurred in shipment of materiel from CONUS up to and including losses sustained in a theater ground combat zone. The models include: inter-theater movement, intra-theater movement, wearout, depot storage and combat. Modular design of the computer system package—consisting of a pre-processor, loss models and a post-processor—permits the military user to efficiently explore the implications of a wide range of situations at various levels of detail. While the system is designed to provide a forecast of wartime materiel replacement requirements, it has a variety of other potential uses. Materiel attrition under various deployment schedules, force levels and tactics can be explored. In addition, extensions of the current development—which includes a capability for forecasting combat personnel casualties—could produce time phased statements of both personnel and materiel replacement requirements.

TA5.7 A Method for Evaluating the Relative Effectiveness of the Field Army Medical Support System, J. H. LANGSTON *and* B. B. LIND, *Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland.*

The Medical Service Agency, Combat Developments Command, is responsible for providing plans which delineate the structure, manpower, and equipment required to efficiently meet predicted medical support requirements for future U.S. Armies. Such a planning function requires analyses which integrate future army organizations and missions and their associated medical workloads with the various levels of the medical support system. The method utilizes three computer simulation models which were designed to characterize medical support functions from the point of casualty generation through the field army hospital. The models have been structured to include all of the factors which influence the medical support function and to reflect this interaction in terms of the pertinent outputs that are measures of the effectiveness of the system. By varying the structure, manpower, and equipment allocation in any desired manner, the analyst is provided information for the relative value of changes in structure or additional allocation of manpower or equipment. From these tradeoff analyses, the most effective combination of manpower and equipment can be developed, which in turn can be used as a basis for justifying the proposed medical support plan.

TA6.1 *A Typical Operations Research Analysis Cycle and its Iteration
MARY A. STAADT, *The Boeing Company, Wichita, Kansas.*

This paper will examine the use of Operations Research in a military aircraft industry by presenting a typical analysis cycle employed for problem solution. Recognition will be given to the relationship of a military requirement to potential problem solutions and to the measurement of their effectiveness. Since response timing for analysis results and precision of initial inputs invariably affect the integrity of these results, various analysis tools applied will be presented. Optimization of the effectiveness of a weapon system performance involves an iteration of the analysis cycle consistent with the available data and budget constraints. Therefore, an example of this iterative process will be shown.

TA6.2 Optimization of Bank Portfolios: A Linear Programming Model, WILLIAM F. BEAZER, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

The paper analyzes the process whereby commercial banks choose their portfolios and develops a model that will explain bank portfolio choice in terms of an objective function whose single parameter is profit. The model used considers explicitly only expected rate of return on the portfolio. The constraints on the portfolio are those applied externally as the result of statute or regulation. The Model converts quite naturally into a linear programming model. All the constraints on the bank can be expressed in terms of inequalities, whose stipulation values are defined in terms of the liabilities of the bank. Thus, the stipulation values will change as reserves flow in or out of the bank and as capital is increased over time. The predictive value of the model is tested by using it to choose quarterly portfolios for 14 large banks over periods ranging from five to seven years, using data taken from quarterly call reports. The loan and investment portions of the portfolios chosen by the model are compared to their counterparts in the actual portfolios. The results are very favorable to the model. In addition, the dual price obtained on the reserves constraint is compared statistically to the interest rate on Federal Funds with very good results.

TA6.3 An Approach to a Technique for Designing an Organization, E. J. MERRICK, *General Electric Company, Missile and Space Division, P.O. Box 8555, Philadelphia 1, Pennsylvania.*

This paper outlines an approach to the synthesis of an organization. It examines an idealized case in the Aerospace regime of systems development and utilization and seeks to identify the necessary and sufficient actions, information and authorization to develop a system from concept to operations. A system is defined in terms of two parameters: its content and its state. The generalized system is assumed to consist of three broadly encompassing elements; they are hardware, procedures, and operators. Six system states are postulated as being concept, preliminary design, design, manufacturing, evaluation, and utilization. These states are clearly interrelated and yet are sufficiently independent either in time or in resources requirements and commitments so that they may be separately analyzed. A matrix of system states and system elements is established. The problem studied is: given (a) that a generalized system consists of the elements stated and (b) that the system life cycle essentially passes through the defined states, what are the *necessary and sufficient* conditions to be met in order to enter and leave a given system state for each respective system element. The requirement for a feasibility analysis and a cost effectiveness analysis to support system state transfers and hence resource commitment decisions is explored via information authorization, and material flow and feedback loops. The purpose of this preliminary study is to identify the necessary elements, examine their interactions and significance and provide insight into organizational responsibilities and structures for effective management. The paper suggests guidelines for approaching establishment of a cost effective organization as well as for supporting justification of proposed technical efforts and their relationship to organizational structures.

TA6.4 An Operations Research Approach to Economic Planning in Underdeveloped Nations, R. L. Grover *and* R. A. Wilson, *Northrop Norair, Hawthorne, California.*

The rate of economic expansion in underdeveloped countries is dependent upon available investment capital and is influenced by the selection of capital investment projects. The selection of projects generally follows a sequence of feasibility studies of the candidate projects with subsequent project funding through the public or private sectors of the nation's economy or by means of Assistance Programs. Feasibility studies require the commitment of limited resources and as such are applicable to evaluation with respect to economic implications and social benefits provided. Since there are more projects requiring feasibility studies than there are funds available and more feasible projects than there are development funds, quantitative evaluation and selective techniques are required to rank the candidate proposals. A model has been developed to provide for feasibility study preliminary evaluation. The potential macroeconomic cost/benefits of each study proposal will provide a measurement and ranking in project priority matrices that will aid in the selection of proposals and the determination of incentives and/or fund sources to be employed. The methodology for preliminary project evaluation developed in this paper also suggests a technique for integrated benefit-cost evaluation subsequent to feasibility study. The main premise of this paper is that efficiencies and soundness in economic and technological analyses may be achieved through preliminary evaluation of the feasibility study candidates.

TA6.5 A Computer Program for More Flexible Inputs to Spatial Diffusion Process Simulations, Forrest R. Pitts, *Social Science Research Institute, University of Hawaii, Honolulu, Hawaii.*

Computer programs involving simulation of spatial diffusion processes, including one prepared by the writer ("A General Computer Model for Spatial Diffusion Processes," 1964 ORSA Joint National Meeting, Minneapolis), have to date required rather rigid inputs. Such programs require that real world data be cut to fit a somewhat Procrustean input format: a mean information field *grid*, and population data in equal-area squares. The present NONCEL computer program in Fortran IV permits flexible determination of the mean information field values, and input of data for odd-shaped political or census areas of varying size. Centroids for these areas may be entered directly, or may be computed from a "minimum aggregate travel" subroutine. The basic Hägerstrand rules for simulations of diffusion are maintained. Output may be simply listed, or displayed in a user-controlled map format. A "trace" option is available if the user wishes an internal record of the history of a simulation.

TA6.6 Automated Production and Assembly of Modular Simulation Programs, JOHN R. METZNER *and* BRUCE H. BARNES, *Penn State University, University Park, Pennsylvania.*

A method of attack is described for the problem of providing an economical tool for obtaining effectiveness estimates for complete ASW weapon systems. Such a tool must be easy to use, inexpensive to maintain and expand, and must provide flexible capabilities, low leadtime, and open-ended fidelity of modeling. The approach described is based on a programming system designed to operate under a batch processing monitor and to make full use of available problem-oriented language compilers. The weapon system description is supplied by the user via questionnaire or responses to the questions at a remote access device. Preprocessing operations then provide controlled statistical mixing of initial conditions and error parameters as desired, selection and possible modification of previously coded program modules, precompilation of specialized language subsystem descriptions into problem oriented language subprograms, and assembly of the machine language programs into program segments. The use of a resident routine package execute time for data and control communication allows independent programming of the modules. A report generator is similarly produced and used to summarize the run's results.

TA6.7 Precision: A Scientific Vice?, G. H. PERRY, *System Development Corporation, Santa Monica, California.*

A widely-held semantic misconception of precision is described. The semantic error that results is sometimes deliberate, sometimes less conscious. In either case, it leads to an over-emphasis on precision when the real quality of interest is accuracy. The implications of this over-emphasis for scientific endeavor are explored, and a recommendation is made.

TA6.8 Cost Effectiveness and Utility Functions for Incentive Structures, LIONEL L. FRAY, WARREN G. BRIGGS *and* JOHN R. RUSSELL, *Harbridge House, Inc., 11 Arlington St., Boston, Massachusetts.*

The development of incentive structures to be employed in R&D contracting requires an analytic expression of the buyer's preferences for alternative outcomes, which in effect, requires the buyer to develop a utility function. This paper first describes the theory by which a buyer aligns his utility with that of the seller, creating the incentive structure. This can be simplified when cost effectiveness analyses can help relate increments of performance and time (delivery) to dollars of incremental cost. When this approach cannot be employed, a utility function must be developed by other means, such as an iterative comparative preference method. An extensive example of such an application is described using a method which employs a computer to help the decision-maker develop an analytic utility function in three dimensions. The mathematical approach can be extended for analytic utility functions in additional dimensions.

TA7.1 Sensitivity of Decisions to Probability Estimation Errors: A Reexamination, PETER C. FISHBURN, *Research Analysis Corporation, McLean, Virginia,* ALLAN H. MURPHY, *University of Michigan, Ann Arbor, Michigan, and* HERBERT H. ISAACS, *System Development Corporation, Santa Monica, California.*

In a typical formulation for decision making under uncertainty with n states of nature and m decision alternatives it is usually not easy for the decision maker to assign to the states probabilities that he is completely satisfied with. This paper addresses itself to several ways of helping the decision maker in such instances. Using the maximum expected utility criterion for the choice of an alternative the paper shows how to go about determining the set of probability distributions on the states that make a given alternative at least as attractive as every other alternative. For the case where the decision maker gives estimates of his probabilities, under which alternative 1 is best, an algorithm is given to determine the minimum changes in the estimates required to make alternative i at least as attractive as alternative 1. It is shown that the probability distribution solution for alternative 1 versus i ($i = 2, \cdots, m$) that is "closest" to the initial estimate is the solution to the problem of finding the probability distribution that is "closest" to the initial estimate and makes at least one other alternative as attractive as alternative 1.

TA7.2 Heuristic Programming Applied to Inventory Problems, KEVIN R. JONES, *The University of Kansas, Lawrence, Kansas.*

The inventory problem makes a useful vehicle for an introduction to heuristic programming because both the problem and the principles of the solution may be stated in simple terms. This paper provides such an introduction as well as the details of the method, the results of some applications, and a discussion of the difficulties involved. In the simplest inventory problem considered, the order point S is chosen at random. The system is then simulated until the order arrives. The cost, both in inventory and shortage (if any) is now calculated for the order period. If this cost is "small" the probability of choosing the same order point is increased. When the probability of choosing any particular S becomes sufficiently large, it is concluded that S is optimum. Difficulties arise in deciding how large a "small" cost is. Furthermore, a poor choice for S may, by fortunate customer arrival, produce a low cost. (And vice versa.) In spite of the difficulties the method is useful because it offers great savings in effort over the Monte Carlo or analytic methods.

TA7.3 Retail IMPACT (Inventory Management Program And Control Techniques) System, M. D. SEVERSKY, *IBM, Data Processing Division, 2651 Strang Boulevard, Yorktown Heights, New York.*

Retail IMPACT System is a recently developed total inventory management system for the retail industry. The system determines automatically what, when, and how much to reorder and generates the purchase order. Retail managers have had no satisfactory system for managing the million plus SKU's (Stock Keeping Units) carried in the main store and branches. As a result of the "explosion" in merchandise assortments and the increase in number of branch stores the actual control of these SKU's has been delegated to clerical personnel who "manage" the inventory. With the application of the latest techniques of operations research in combination with an IBM System/360 Data Processing System, it is now possible for retail management to select and maintain optimum levels of inventory, service, and work load. The system adjusts itself to changes in the parameters of demand, leadtime, SKU characteristics, and management policies, and measures continuously its own performance. An incorporated systems simulator allows management to simulate the present and the new system, to select optimal policies, and to test Retail IMPACT system in a dynamic context before installation.

TA7.4 Errors in Adaptive Forecasting Formulas, J. L. BRENNER *and* D. A. D'ESOPO, *Stanford Research Institute, Menlo Park, California.*

The deviation of actual sales (or other time-dependent statistics) from a model of sales will give rise to forecasting errors that are enhanced, damped out, or shifted in phase, depending on the particular formulas that are used for forecasting. Following R. G. Brown, P. Winters, and Theil, Nerlove, and Wage, we start from a general set of forecasting formulas, but make fewer assumptions than those authors about deviations from the model, and obtain a more extensive collection of results. In particular, we show how to treat errors not serially uncorrelated, and how to investigate forecasting formulas of order higher than second.

TA7.5 A Conditional Binomial Assay Model for Advertising Sales Effectiveness, WILLIAM J. WROBLESKI, *The University of Michigan, Ann Arbor, Michigan.*

Advertising frequently is interpreted as a "communications" process. From this point of view, after initial perception and following a hierarchical sequence of personal evaluations ranging from a cursory examination of form to detailed message content analysis, advertising is transformed into an information module capable of forming, changing or retaining individual attitudes and beliefs. For purposes of managerial decision making related to economically efficient capital resource allocations, however, this communications theory interpretation of advertising must be extended and advertising related to purchasing behavior. In this paper properties of a conditional binomial probability model for relating advertising to sales over time are explored, including the effects of serial correlation found between sales generated as a time series by a stochastic process of this type. This probability model can be specified by a functional parameterization using an advertising response function related to the "propensity" of individuals to purchase a given product. For a particular individual, of course, the propensity to purchase a particular product changes with time. It depends not only on the direct or cumulative effects of advertising, but on other economic and structural variables as disposable income, product need, usage and replacement patterns, as well as attitudes and beliefs held about the product. Moreover, each of these factors not only contributes its own separate effect, but they interact with each other to create purchasing behavior. Therefore a conditional binomial stochastic process parameterized by an advertising response function related to the purchasing propensity of individuals provides an advertising sales effectiveness model for assaying over time the effects on sales of advertising together with other determinants of purchasing behavior and their interactions.

TA7.6 Statistical Techniques Applied to Testing of Explosive Devices, R. R. Boyce, *and* J. E. Schonblom, *Martin Company, Orlando, Florida.*

The details and generalities associated with planning, conducting, and analyzing the results of a particular experimental program are discussed. The experimental program was performed in order to acquire data which could be used to establish a correlation between controlled changes in design parameters and changes in the speeds and dispersion of discrete fragments emitted from an exploding warhead. The generalities cover test results and difficulties which are peculiar to the area of explosive testing: details cover experimental set ups and statistical procedures which are used to plan the program and analyze the data. In particular, emphasis is placed on the principles of Factorial Design and ANOVA. The former are used to design the experimental program: the latter is used to highlight trends in the data by the simplified process of testing various hypotheses at the 5 percent level of significance.

TA7.7 Concept Mapping: Creation of Indices with Specified Estimating Properties, R. D. Jones, *University of Missouri, Kansas City, Missouri.*

Indices, single measures for multifarious conditions, are useful in the examination of large, formally organized bodies of data and in building simple models from empirical data. A new technique for index creation, concept mapping, provides a method for ranking various phenomena by index scores according to the least squares expectancy that they will manifest some multivariate condition designated by relative or specific values for known variables. The user can demand a greater expectation for some variables than for others and can specify the index to be statistically independent of still other variables. The procedure might be viewed as an operation inverse to multiple linear regression—both in that a single predictor and several criterion variables are involved and in that values related to the regression weights are given while the problem is to solve for values of the predictor: the index scores. Other interpretations are as a solution to the rotational problem in factor analysis and as a procedure for creating indices analogous to the "ideal types" of the sociologist, Max Weber. A solution procedure is given. Potential uses and limitations of the technique are discussed.

TA7.8 Poker—A Time-Series Analysis of 350 Games, M. H. Garnholz, *TRW Systems Group of TRW Inc., One Space Park, Redondo Beach, California.*

The card game of poker is played by millions. However, due to the many variations it is a difficult process to analyze. This variety coupled with the psychological interplay of the participants makes poker perhaps more similar to the stock market rather than the more usual gambling games, such as blackjack or roulette. An interrupted but continual game of fixed betting limits having essentially the same players throughout was observed. An unique characteristic was that the monetary win/loss outcomes of more than 350 sequential gambling sessions were recorded for each player. Debts were settled after each set of 10 sessions. The appearances of the players' cumulative win/loss records versus time are quite similar to many individual stock price movement patterns. Trend analysis techniques used in "technical" trading are considered. Like in the market, there are price increases (increased winnings) partially due to the astuteness of the "investor" and partially due to the inherent quality-demand characteristics of the stock itself (the cards). Several interesting conclusions are drawn. Because of the large session-to-session variations in winnings of most players, very few realize their own actual gain or loss over a long period of time. Secondly, the opinions of nearly all players as to who are "good" players and who are "poor" are quite contrary to the actual long term records. Perhaps, like the stock market, the investor who merely makes 10% of his money, steadily, appears to be nowhere nearly as successful as the man who makes 300% and whose even larger previous losses are either unknown or forgotten.

TA7.9 A Behavioral Model of the Prisoner's Dilemma, J. R. EMSHOFF, R. W. BLANNING, *and* A. G. RAO, *University of Pennsylvania, Department of Operations Research and Statistics, Philadelphia, Pennsylvania.*

Efforts are underway at the University of Pennsylvania to develop a theory of human behavior in conflict situations. A part of this effort has been directed towards constructing an explanatory model of a player's behavior in the Prisoner's Dilemma. It is hypothesized that a player's choice of strategies depends on the past history of the game and upon four parameters. These parameters are the following: competitiveness, memory, foresight, and rigidity. The competitiveness parameter quantifies the degree to which a player wishes to maximize his own gain as against maximizing the difference between his gain and his opponent's gain. The memory parameter determines the player's ability to use past data in estimating the probability distribution of his opponents' responses to his possible strategies, using an exponential smoothing scheme. The foresight parameter is used to estimate the present value of future gains for any strategy. The rigidity parameter expresses a player's inability to adapt to indications of changes in an opponent's strategy. A program has been written and used to estimate player parameters from actual game data. The paper will describe the above model in detail and report results of statistical analysis of the parameters. Other methods of validation will be discussed.

TP1.1 *A Study in Wave Theories of Traffic Flow, C. K. WOJCIK *and* L. A. PIPES, *University of California, Los Angeles 24, California.*

This study presents mathematical models explaining the "wave phenomenon" as observed in actual traffic. The first part of the paper deals with calculation of a safe distance between two vehicles in line. It is assumed, throughout the remainder of the paper, that all drivers in the line of vehicles do try to maintain this safe distance. In constructing the transfer function of the system, natural characteristics of the driver and the vehicle are considered. These characteristics are: the time delay of the driver's responses, the dead zone caused by the driver's insensitivity to signals of small magnitude, and the saturation resulting from the performance of the vehicle. Using the derived set of equations, describing these characteristics, the behavior of a line of vehicles in one lane is evaluated for various types of input (accelerations and decelerations of the leading vehicle) by means of an analog computer.

TP1.2 *Ship Scheduling in the Kiel Canal and Statistical Aspects of Optimization Techniques, H. Mertin, *IBM Germany, Berlin, Germany.*

The problem of guiding ships through a system of canal sections and shunting places can be mapped onto a multi-stage binary decision problem. The problem of minimizing weighted delay sums or equivalently maximizing the total throughput is that of finding a shortest route through the decision tree. Some techniques leading to near optimal solutions are discussed and analyzed by statistical methods. The problem has an interesting relation to that of the vehicle actuated control of a single intersection.

TP1.3 *Truck Driver Scheduling, A. Bomberault, C. Lemke *and* E. Wrathall, *IBM Data Processing Division, White Plains, New York.*

The truck scheduling problem seeks to determine the most profitable assignment of drivers to routes such that: (1) loads are delivered to destinations within a specified time after receipt; (2) drivers drive only a limited number of hours a day; (3) drivers are home at the end of the week. The cost to be minimized consists of hourly wages, layover costs for drivers away from home base, bonus payments for being off duty and away from home more than a specified time. An algorithm, for solving this problem, neglecting integer conditions, is developed using L.P. with a column generating technique utilizing Dynamic Programming.

TP1.4 *Parametric Relations in Transit Route Structure Models, Ernest B. Cohen *and* Solomon Moldoff, *General Electric Co., King of Prussia, Pennsylvania.*

The recent re-appraisal of transit systems as part of the total urban transportation complex has raised a requirement for route planning models. The present route models used for high-way planning are not generally applicable to transit planning. This paper explores a number of models of varying degrees of complexity which could be used in the analysis of over-all system configuration. The optimizing function in these models is door to door travel time rather than monetary cost, since time is the major travel cost in most urban transportation. Total travel time is affected by the distribution of origin and destination points, the routing over high-speed transit and local feeders (including walking), the spacing of stations, vehicle headway, interconnection delays, as well as vehicle speed. The simplest case is a single transit line without interconnections in a uniform density urban area. This basic linear model of a single transit line is expanded to spiderweb, grid, and lobe route plans. The straight line transit model is also elaborated to cover other population distributions and operation modifications such as express service. Since detailed models are generally not available on which to base parametric relations between various alternatives, this paper points out the areas where future work will be required.

TP1.5 *Continuum Assignment of Traffic on a Circular City, TENNY LAM *and* G. F. NEWELL, *Institute of Transportation and Traffic Engineering, University of California, Berkeley, California.*

Consider a circular city with a radial and circular street network so large that it can be approximated by a continuum of roads and a continuously varying distance between points. Traffic enters at the circumference, each car having a joint probability distribution of origin and destination that depends only upon the relative angle between original and final radii. Each driver chooses a path of minimum travel time. Assignments of traffic will be given under the assumption that the velocity of traffic at any point depends upon the flows at that point. This extends some work of Smeed and Haight who considered a similar problem with no flow dependence of the velocity. In the present model, however, the congestion in the center will automatically force some of the traffic to avoid the center.

TP2.1 *Public Works Projects, BENJAMIN CHINITZ, *Economic Development Administration, Washington 25, D.C.*

Under the Public Works and Economic Development Act of 1965, we have the responsibility of allocating funds to finance public works projects in qualified areas. These are areas which, generally speaking, have relatively high rate of unemployment and/or a relatively low level of income. For the current fiscal year, our budget is $200 million and we expect to receive applications adding up to a billion dollars. The problem then is to develop criteria for allocating these funds to maximize the objectives of the Act which are to reduce unemployment and to raise the level of income. The analytical task can be divided into two categories: the first is to develop methodology for estimating the consequences of the investments which we would finance, and the second is to develop a system for weighing the benefits and costs so that we can compare one project to another.

TP2.2 *Program Budgeting for Natural Resources and Education, WERNER Z. HIRSCH, *University of California, Los Angeles, California.*

Three major aspects of program budgeting will receive attention with regard to the planning and management of our natural resources and our education system. They are the structure of the program budget; the analytic demands of the program budgeting procedure; and the administrative-organizational aspect of the program budgeting process. Efforts will be made to present a Federal natural resources and education program budget, respectively, for a recent period and some cost effectiveness illustrations.

TP2.3 *Effective Resource Allocation in Universities, HARRY WILLIAMS, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

Administrators charged with the rational allocation of university resources must be able to visualize and analyze their pattern of choices among alternatives. Present university budgets are poor instruments for communicating the type of information required to gauge the effectiveness of resource allocations. They do not exhibit or analytically support the level and direction of activities over which university administrators have cognizance. It is essential to so derive a budget that it will reflect the larger purposes and long-range programs of the university. Allocations can be supported by analytical studies which ask *why* a university has so distributed its limited resources; hence a logical approach to the efficient use of university resources involves some variant of a theory of constrained choice. Tools are available which could aid in a shift in emphasis from pure accounting data budgets to program-derived, resource-oriented budgets. Analytically supported program budgeting will raise the right questions and direct attention to important trade-offs. Rational analysis can provide a hedge against the lack of clearly perceived goals or purposes. Resource-allocation budgets based on operations research and economic analysis provide a tool with which the decision-maker can focus and sharpen his grasp of alternatives.

TP2.4 *Cost-Effectiveness Analysis in the Administration of Justice, JULIUS MARGOLIS, *Department of Economics, Stanford University, Stanford, California.*

The public product, justice, is designed by courts and legislatures acting in the most august role of sovereign but the provision of this public service is subject to the less hallowed forces of conservative professional practices, legislative budgetary constraints, traditionalistic administrative procedures. Congestion and procedural rules cause high private and social costs of justice. The federal government is the most important party to court actions in civil and criminal cases. In criminal cases it can guide its actions by a model to solve for the optimum amount of crime, considering the private costs, the production function of punishing, apprehending and correctional activities, subject to democratic constraints on the scope of public acts and police and other official procedures. In civil cases the federal government can design its activities so as to take into account the social costs of its acting as a litigant. This will necessitate introducing less costly procedures, assessing costs against the government for its damage creation and acceptance of an improvement in the public welfare as a guide rather than the convenience of the government.

TP2.5 *System Analysis of the Los Angeles Police Department Crime Information System, HERBERT H. ISAACS, *System Development Corporation, Santa Monica, California.*

The Los Angeles Police Department and System Development Corporation have been jointly involved for several years in a program of research, experimentation and system analysis of the applications of advanced computer techniques to a metropolitan police department. A six-month system analysis and design effort was concluded in December 1965, which provided an operating system description of a first-phase information system to support the Police Department's operational and management requirements. The Phase I system includes the following components: (1) The processing of crime data on a city-wide basis, including the field reporting of events in remote locations; entry into a central computer file for correlation with similar data; dissemination of abstracts back to the field locations, both automatically and upon demand; the production of the management reports required for proper evaluation and deployment of manpower; assistance to the investigator in retrieving relevant crime data; and the automatic dissemination of information to concerned county and state agencies concerning the crime activities, stolen property, individuals and vehicles involved. (2) The incorporation of data on persons interviewed in the field and the correlation of this data with possible crime occurrences in the same area and at the same time. This field interview data is currently collected by patrol officers throughout the city, but has limited application because of the manual nature of the file system. With the new system, this data would be available for computer retrieval and matching with selected crimes. (3) The maintenance of a real-time inquiry system for warrants and other wants for individuals. This system would be correlated with the service of warrants and related information given to patrol supervisors in the outlying divisions. (4) A total inventory and processing of arrests and booking information, maintaining up-to-date information on individuals who have been arrested by Los Angeles Police Department. This system will be compatible and communicate directly with the arrest and jail system processing of the county sheriff. This paper discusses the approaches taken and special problems involved in the functional analysis and operating system design for a major metropolitan police department. Some of the special requirements related to the unique problems of state and local government are also discussed, particularly in terms of how they affect the classical system analysis process.

TP3.1 *Operations Research and Applied Logistics, COLONEL EUGENE C. PARKERSON, *Hill Air Force Base, Ogden, Utah.*

Despite many years of operations research on various problems of military logistics, there are relatively few instances where the results of the research have been quickly or completely implemented by the military services. What is the nature of the problems involved in bridging the gap between theoretical concept and operational reality? The problem of implementation is discussed both from the point of view of the researcher and the logistics practitioner.

TP3.2 *A Systems Approach to Base Stockage: Its Development and Test, H. C. CAMPBELL, *The RAND Corporation, Santa Monica, California, and* T. L. JONES, *Ent Air Force Base, Colorado.*

The "systems approach to base stockage" is a comprehensive proposal for an improved method of setting stock levels of reparable spare parts at air bases. The main features of the inventory model are that it deals with a system, or aggregate, of spare items, rather than one at a time; it maximizes systems effectiveness for a given spares budget; and it employs a form of Bayesian estimation in predicting demand (the basic process is assumed to be stuttering Poisson). One of the most difficult aspects of operations research is finding the opportunity and the method for operational evaluation of complex proposals of this type. In this case, the model predicts the level of effectiveness (measured in "fill rate") inherent in a given budget allocation. Hence it can be tested directly for its prediction ability, as well as more qualitatively for the adequacy of the logistics support provided. This was done at an Air Force base. The results of using stock quantities set by the model were measured over a six-month period, and found to be in good agreement with the target. No adverse effects on operations were reported. The development and test experience are summarized in the paper.

TP3.3 *A Model for the Design and Evaluation of Air Cargo Systems, ROBERT B. FETTER, *Yale University, New Haven, Connecticut, and* RONALD C. STEORTS, *Research Triangle Institute, P.O. Box 490, Durham, North Carolina.*

The objective of this work was to develop procedures that could be used in the design and evaluation of air cargo systems. The evaluation problem is one of determining the cost and performance of a particular flight structure (planes, flight routes, and schedules). The design problem, a much more complex one, is to determine the flight structure that will move the required cargo between locations with minimum cost. Realizing that the design problem could not be solved analytically, it was decided to concentrate on the development of computer routines whose outputs would give a cargo system planner information useful in the design process. In both the design and evaluation problems it is necessary to generate alternative routes between source-destination pairs over which cargo is to be moved. A route generating program produces these alternative routes for each source-destination pair and files them in sets ranked on some route attribute such as shortest elapsed route time or least cost. Cargo shipments are then allocated to these candidate routes by one of several linear programming formulations with the route generating program automatically producing the input tape for the linear programming routine. Results of using these procedures for an actual air cargo system, as well as the associated computer time requirements, will be discussed.

TP3.4 *On-Line Control of Maintenance Activities, STEPHEN M. DREZNER *and* RICHARD L. VAN HORN, *The RAND Corporation, Santa Monica, California.*

This work is based on research performed at RAND on an automated control for base-level maintenance. The major emphasis in the paper is on applications of real-time computer systems to the control of maintenance activities. How can the computer be used to enhance the control function? The allocation of tasks to men or machines, the man-machine interaction, and the hoped-for synergetic effect are discussed in terms of how they affect the design of the control system. Most of the maintenance control functions are not unique and are described in general terms. For example: data acquisition, information storage and retrieval, information display, and monitoring. Functions such as scheduling and dispatching, which are the more interesting activities from the standpoint of decision making, have some unique features but can be generally described in terms of search and choice theory. Observed maintenance scheduling performance is explained in terms of search and choice algorithms.

TP4.1 *Highlights of a Dynamic System Description Language, H. S. Krasnow, *Advanced Systems Development Division, IBM Corporation, 2651 Strang Blvd., Yorktown Heights, New York.*

A system description may be viewed as consisting of two prime components: (1) a static representation, and (2) a dynamic representation of the real world. The first is concerned with existence—what are the components of the system that will be caused to exist in the model and what are the structural relationships that will be recognized between the components. The second is concerned with change—what state changes are possible in the model and what are the sequence relationships between these changes. This paper outlines the major features of an experimental language which employs a unified treatment of static and dynamic representation. The dynamic entity is termed a "process," and possesses all of the capabilities of a static entity. In addition, a specific pattern of behavior is associated with a process, hence it defines a sequence of events. A process is capable of existing over simulated time, of interacting directly or indirectly with other processes, of dynamically incorporating other processes as subprocesses, and in general of conditioning its performance in response to the state of the model. The dynamic structuring capability that results facilitates a modular approach to model construction.

TP4.2 *Incremental Simulation, M. Greenberger, *Center for Research in Management Science, University of California, Berkeley, California.*

The paper describes an on-line system for building and running simulation models incrementally. It was developed by extending the mechanism of a multipurpose facility for on-line computation called OPS. The user of the OPS system works from a typewriter terminal of a time-shared computer. He constructs his simulation by programming activities (or events, as in SIMSCRIPT). An activity is either a subroutine, called an operator, or a program of subroutines, called a compound operator. One special compound operator, called the AGENDA, is used as a dynamic schedule of activities. Since their execution is interpretive, compound operators are easily modifiable from the terminal; or they can be compiled for a gain in running efficiency. The user may interrupt a simulation run, make on-line calculations by means of standard operators, add a new activity, modify an old activity, edit the AGENDA, then resume the run. Access to data and operators is symbolic. Standard operators permit unit processing of entire arrays, such as vectors, matrices, and queues. A variety of statistical operators, including multiple regression and Chi Square, is available. In all, over seventy operators are provided. Allocation of storage is dynamic, and the user may add any number of operators of his own design, including conventional subroutines from existing program libraries. The OPS system is fully described in the book ON-LINE COMPUTATION AND SIMULATION: THE OPS-3 SYSTEM, published recently by the MIT Press.

TP4.3 *Generalized Models of Information Processing Systems, G. K. HUTCHINSON, *Lockheed Missiles & Space Company (LMSC), Sunnyvale, California.*

LMSC operates one of industry's largest, centralized computation centers, processing administrative, scientific, data reduction and on-line jobs. In order that this work may be accomplished with speed and economy, LMSC performs a continuous evaluation of computer hardware and software systems with respect to processing requirements. In support of this evaluation activity, LMSC has performed research in the development and use of descriptive models of Information Processing Systems since 1959. Recent products of this program are two generalized, user oriented, SIMSCRIPT based models, the Lockheed Multiprocessor Simulation Systems (LOMUSS) I and II. LOMUSS I views an information processing system as an extended, augmented job shop with work flowing from machine group to machine. Innovations, compared with the classifical job, include slave machines (in addition to master machines) and PERT-like job routings. Over 20 LOMUSS I models have been constructed and utilized in applications from analysis of present systems to design of future systems. LOMUSS II is designed to describe the dynamic characteristics of a single computing system (i.e., a multiprocessor such as the CDC 6600) at the hardware interrupt level. Descriptions of the hardware components, the system workload and the executive control routines are included in LOMUSS II. The LOMUSS models and applications will be described.

TP4.4 *SimOptimization Techniques: Iteration Two, E. L. LUTHER AND H. N. MARKOWITZ, *California Analysis Center, Inc., 225 Santa Monica Boulevard, Santa Monica, California.*

The objective of the SimOptimization research is to provide efficient, automatic techniques for locating improved (but not necessarily optimum) solutions to simulation models where analytical optimization techniques cannot be realistically applied. The purpose of this paper is to report the current stage of development of SimOptimization techniques and the empirical test results. The tests were made with a simple task-resource model (TR-2) which may require more than one resource per task. The decision criterion, model formulation and implementation are discussed. The results of empirical tests are presented, including an analysis of the convergence and efficiency of the techniques. The effect of imposing restrictions on the allowable rate of change per resource is also investigated. For completeness, a brief summary is given of the results obtained with the TR-1 model (used in iteration one) which required a single resource per task. Finally, the work currently in progress is described and plans for future research outlined.

TP5.1 *Two Types of Task Teamwork, L. S. CHRISTIE, *System Development Corporation, Santa Monica, California.*

Experimentation on human information handling tasks has shown two sharply contrasting processes of the emergence of organization with equally contrasting end results. One is global, gradual, and satisfying; the other local, abrupt, and optimizing. Dependence of type of organization and path of organizational planning effort, and task structure will be discussed. Implications will be drawn for a technology of organization design distinct from, and supplementary to a science of organization development.

TP5.2 *A General System Model for Investigating Feedback Signal Paths to the Secondary/Vocational-Technical School, LEONARD C. SILVERN, *Education and Training Consultants, 979 Teakwood Road, Los Angeles, California.*

There is little doubt that schools in the K-12 range in the United States will have to change drastically if they are to optimize their education function. Little is known about secondary schools in general and the secondary/vocational-technical schools in particular regarding *normal* change functions. Until *normal* change functions are identified and studied, *special* or abnormal change functions cannot be accurately characterized. It is believed that feedback signal paths into the school are multitudinous and are of various figures of merit. A general system model to investigate these stabilizing signal paths is anasynthesized. Such a model utilized operates research techniques in a behavioral/managerial science environment. It is concluded that many *normal* signal paths resulting from several hundred years of experience are ineffective in producing changes which are essential for the day-to-day requirements for system effectiveness. Two flowchart analogs are utilized to describe the phenomena.

TP5.3 *Operations Research and Cost-Benefit Models for Innovation in U.S. Public School Systems, NORTON F. KRISTY, *Astrodata-Simutech, Inc., Los Angeles, California.*

It is difficult to model operational performance and effectiveness in U.S. public schools in a way that will permit some reasonable evaluation of incremental finding for educational innovations. Yet this must be done if we are to determine which of the many experimental programs have value and if we are to force the pace of implementation of these new instructional methodologies. This paper will describe a number of micro-models which may be helpful in generating the informational basis for decision making. These models are oriented to the decision making requirements of the local school district, yet an attempt is being made to have them sufficiently flexible so that one can combine and aggregate the results into informational guidelines useful at the federal level. Some early results of the study will be described and implications drawn.

TP5.4 *Implementation of Operations Research Results: Contributions from the Behavioral Sciences, JOHN V. ZUCKERMAN, *University of Southern California, Los Angeles, California.*

The literature is being added to daily with descriptions of operations research projects which were never implemented, or which failed to achieve full implementation. It is hypothesized that a major cause is the lack of attention to plans for implementation based on an understanding of individual group behavior. The development of such an implementation plan is described, with examples. References are made to the relevant behavioral science research on the implementation of technological change.

TP6.1 *A Two-Stage Forecasting Model: Exponential Smoothing and Multiple Regression, DWIGHT B. CRANE AND JAMES R. CROTTY, *Mellon National Bank and Trust Company, Mellon Square, Pittsburgh, Pennsylvania.*

Smoothing of time series and multiple regression are two important classes of forecasting techniques. In the smoothing approach, the variable of interest is forecast on the basis of an extrapolation of the underlying pattern of its past movement. While a smoothing model provides a very useful way of utilizing information contained in the history of the forecast variable, it neglects information contained in related variables. A multiple regression model can correct this potential deficiency, but unless the model uses only lagged values of the independent variables, forecasts of these values are required. This paper presents a technique which combines the advantages of both approaches. An exponentially smoothed moving average model is used to forecast values of the dependent variable and/or selected independent variables as desired. These forecasts, along with data for other (lagged) independent variables, are then used as inputs to a multiple regression program. The observations are selected sequentially by the regression model so that each equation is based only upon data which would have been available at the time of the forecast, and the coefficients of the equation are updated as new information becomes available. The final section of the paper describes two successful applications of the two-stage model.

TP6.2 *Optimal Level Debt Schedules for Municipal Bonds, KALMAN J. COHEN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania, and* FREDERICK S. HAMMER, *Bankers Trust Company, New York, New York.*

An important restriction which frequently appears in the bid specifications for new issues of municipal bonds is that the total dollar amount to be paid for both principal and interest by the municipality in any given year of the issue must not be significantly different from the total dollar amount to be paid in any other year, i.e., that the total payout pattern over the lifetime of the bond issue must be substantially level. Because of this "level debt" restriction, the inter-relationships between coupon schedule and maturity schedule appear to underwriters as being very complex. Given the requirements of the marketplace, bond market professionals presently employ trial-and-error techniques in an attempt to determine the admissible coupon and maturity schedule which will lead to the lowest possible net interest cost. The present paper shows that the determination of this optimal coupon and maturity schedule for a level debt issue can be readily accomplished by linear programming techniques.

TP6.3 *Application of Credit Scoring in a Bank, G. RANDOLPH JENKS, *Security First National Bank, 561 South Spring Street, Los Angeles, California.*

Multiple linear regression techniques were employed to establish the initial coefficients for determining credit worthiness. The resulting indices of credit worthiness for sample populations with known loan outcomes were characterized by normal distributions with considerable overlap. The method of controlling the loan portfolio to a desired performance level in these conditions is that of measuring actual loan distributions against a minimum acceptable composite distribution of good loans, slow loans, and charged-off loans. Depending upon the nature of the deviation, control is exercised by either changing the cutting scores for organizational units or by influencing the acceptance at specific branches. Changes in customer behavior and/or changes in the effect of the implicit credit screen prior to formal scoring are accommodated in score revalidation at frequent intervals.

TP7.1 *Some Further Results in the Theory of Stochastic Duels, C. J. Ancker, Jr., *System Development Corporation, Santa Monica, California.*

The theory of the simple (one versus one) duel is extended in this paper. Included are the general expressions and examples for two situations namely (1) where time of projectile flight is not assumed to be zero and (2) where the antagonists fire fixed bursts of evenly spaced rounds at random intervals between bursts. Another model in which the time of flight varies linearly with elapsed time is also considered.

TP7.2 Solution of the Extended Lanchester Equations of Warfare Used in the TWSP, Fred K. Dashiell *and* William W. Fain, *Aerospace Sciences, Douglas Aircraft Co., Long Beach, California.*

The purpose of this paper is to explore some of the mathematical aspects of the extended Lanchester Equations which are used in the Tactical Warfare Simulation Program (TWSP). A series solution for the set of differential equations is obtained under rather general conditions. A simple example of the attrition obtained from exact solutions is compared to the current computation procedure used in TWSP. Differences are found to be minor.

TP7.3 A Computerized Quick Game for Deployment Analyses, Richard E. Zimmerman, Dudley Edwards, Edward P. Kerlin, Donald Mader *and* James D. Pomeroy, *Research Analysis Corporation, McLean, Virginia.*

There is now developing in DOD an interest in all computer simulations of the ground battle at a high level of aggregation. Unlike war games, simulations permit extensive sensitivity analyses of the impact of the numerous and highly uncertain assumptions on the outcome of the war. Basic to the use of a highly aggregated computer simulation is the feeling that the loss in detail and realism of a simulation over a war game is more than compensated for by the ability to repeat the calculations for a variety of situations. This paper describes such a simulation. The basic feature of the earlier Quick Game involved is that division rates of advance are a function of force ratio. Force ratios are based on weapon firepower scores which, in turn, are in part based on the historical casualty production rates and in part on theoretical studies. To this body of rules have been added (1) a logistics model which makes explicit the flow of tonnage over an aggregated LOC, (2) a tactical air model distinguishing between close support and interdiction and (3), a simple tactical decision model which substitutes for the missing players.

TP7.4 Application of Dynamic Programming to the Problem of Firing Missiles at Targets Whose Values Change With Time, ALAN WASHBURN, *The Boeing Company, Seattle, Washington.*

We consider the firing of missiles with time variable kill probabilities at a large group of targets with time variable "values," using a perfect bomb damage assessment system. Our object is to determine the greatest number of target value units achievable, as well as the optimum missile firing procedure, under the assumption that the expected value of the number of targets killed is always killed. A dynamic programming solution of the problem is found, and typical results are presented.

TP7.5 Measures of Effectiveness for Anti-Aircraft, Guided Missile Systems, EDWARD M. HADRO, *Raytheon Company, Bedford, Massachusetts.*

The performance of an anti-aircraft surface-to-air missile system is traditionally described by a "burst-locator" diagram which shows in the ground or vertical plane the loci of intercepts that a firing site can achieve against an attacking force specified in terms of velocity, altitude, raid size and configuration and radar or IR signature. The burst-locator is derived by relating subsystem penetration (acquisition sensor, fire control system, launcher, interceptor missile, etc.) in the framework of the system operational sequence and as limited by the operating environment (terrain obstructions, weather, or ECM degradation). Burst-locator diagrams merely describe *system performance* and do not relate this performance to the military value of the system; therefore, these diagrams, in themselves, are not satisfactory measures of system effectiveness. This paper describes some simple methodology for relating the geometry of the burst-locator to system effectiveness in performing specific air defense objectives such as forward area air defense and denial of penetration.

TP7.6 A Basic Operations Research Approach to the Determination of Rifle Operational Hit Probability, H. C. ALBERTS, *Stanford Research Institute, P.O. Box 316, Fort Ord, California.*

There has been for many years a systematic program within the Army for testing new and improved rifles. Within recent years a study and analysis of prior criteria for rifle evaluation and selection has been carefully reviewed and there has been generated a comprehensive field experiment to determine whether it is now possible to select a set of engineering and experimental criteria which will yield operational rather than engineering hit probabilities. This paper presents the rationale for developing, using field operational research and experimentation techniques, criteria for weapons testing. Data obtained from such tests are included and a comparison is made with previous test results.

TP7.7 Redetecting an Inexactly Located Submarine, F. R. S. DRESSLER, *Bell Helicopter Company, P.O. Box 482, Fort Worth, Texas.*

The paper considers the evolving Anti-Submarine Warfare (ASW) tactic of using a manned helicopter operating from and with a destroyer escort to redetect, localize, classify, and kill enemy submarines. The redetection phase is considered critical and is analyzed. A range of operational conditions are considered: (1)

Timely data are available concerning the submarine's location. (2) Contact is lost; all that is known is that there is a submarine somewhere in an ever enlarging area centered at the point of lost contact. (3) Contact is lost, but the escort had sufficient contacts to predict the future course of the submarine. The concepts of Detection Area and Diffused Detection Function are introduced as new tools to quantify the redetection capability of the ASW system. Both sensor capability and system random and bias errors are considered in a general development. Important system parameters are identified, and their influence on system capability is shown in simple, closed-form solutions. The analysis demonstrates that a "balanced" system is required. That is, both system random and bias errors must be small to give high redetection probabilities. Also, timely action on the part of the helicopter is important when the escort loses contact with the submarine; especially when there are significant errors in the ASW system. The resulting solutions are well suited to develop specifications for future ASW systems and conduct cost-effectiveness analyses.

TP7.8 Cost-Performance Analysis of an IR Mapping System, EUGENE C. MIKELONIS, *HRB-Singer, Inc., Box 60, State College, Pennsylvania.*

A cost-performance analysis is presented for a specific problem of resource allocation. Functional relationships are established in the form of a family of curves, and these are used to adjust the cost-performance relation for various operational modes. Specifically, the problem involves the assessment of several infrared reconnaissance system configurations for the mapping of nuclear fires in a post-attack period. In addition to an attack-indifferent technique for determining which areas should be mapped, emphasis is placed upon the method of performing a cost analysis of the alternative system configurations. Optimum allocations of IR equipment are prescribed for various situations and then a cost-performance measure is expressed for each system alternative in terms of the time required to provide information to the decision maker. This performance measure can be adjusted to account for various data transfer and processing techniques as well as other system characteristics. Special consideration is given to the problem of converting the value of intermediate system output into a meaningful measure, since it cannot be compared directly to the cost-performance curves. This is done by a system of weightings to normalize these values so that they may be incorporated into the cost-performance evaluation. Optimum system configurations can then be specified for any fixed cost or, alternatively, the cost can be determined for an optimum system configuration.

TP7.9 Methodology for Estimating Casualties from Fallout Attacks, FLOYD I. JOHN, *Stanford Research Institute, Menlo Park, California.*

A realistic comparison of the effectiveness of active and passive defenses depends strongly on an accurate assessment of the casualties resulting from fallout attacks. In developing an appropriate methodology for performing this assessment, the following factors were taken into consideration: (1) the probable methods used by the offense in choosing the number and locations of weapons, (2) the constraints imposed by the defense, and (3) the random factors which affect the number of casualties. The results of a preliminary evaluation of the magnitude of the threat from fallout attacks will be presented and the influence of each of the above factors will be discussed.

FA1 Computers and Operations Research, (Panel). *Session chaired by H. R. J. Grosch, General Electric Co., TEMPO, Santa Barbara, California.*

Because of the wide applicability of forthcoming direct-access information systems, the computer session has been planned to provide for audience interaction. The speakers will first make direct presentations in their areas of personal interest—service operations, information retrieval, and time-sharing—and then with the chairman will attempt to relate the promised system hardware and software potentials to audience interests. It is hoped that questions will center around the new techniques of querying remote data and computational facilities.

FA2 Measuring the Effectiveness of Our Military and Political Effort in Viet Nam, (Panel). *Session chaired by* LEONARD UNGER, *Deputy Assistant Secretary of State for Far Eastern Affairs (Former Ambassador to Laos), Washington 25, D.C.*

Choosing the right measure of effectiveness and estimating it carefully have been emphasized by the Department of Defense during the past six years as essential elements of good decision making. The lesson has been well learned by those making R&D and procurement decisions on weapon systems. Good techniques exist; they are being applied, and research continues on making them still better. Should equal emphasis be given to measuring the effectiveness of our activity in Viet Nam? If we devoted more effort to devising ways of measuring effectiveness in this field of OR, would our management of limited wars improve? Can even the general principles of effectiveness measurement which have validity for weapon systems be used in a field where intangibles and unmeasurables abound? Do we in fact know how to measure the military and political effectiveness of our effort when military and political goals are as hard to disentangle as they are in Viet Nam? If not, how can we proceed with confidence that a given input will achieve anything like the desired results, militarily and politically? If not, should we not be spending more time and money on research aimed at improving our capabilities to make this kind of estimate? Finally, what modifications of our analysis techniques should or can be made to adapt to this complex field of study? These and similar questions will be addressed by this panel. The effectiveness of the panel will be measured not against the number of these questions that get definite answers (probably none will) but by how clearly the panel illuminates all facets of the total problem of measuring effectiveness in Viet Nam and by how sharply it defines the issues.

FA3.1 *The Role of Transport in Developing Countries: A Development Planning Model, PAUL O. ROBERTS, JR., *Harvard University, Cambridge, Massachusetts.*

Economic development like other human endeavors appears to be strongly influenced by transportation. The exact mechanisms of this influence are as yet not well understood. The purpose of this model is to explore the interface between the economy of an undeveloped nation and its transportation system. The model consists of two major parts, a macro-economic sector and a transport sector. The macro-economic portion represents the yearly operation of the overall economy by means of a national input-output table. Production and consumption are then regionalized considering population, capital investment and regional profitability. The transport sector determines market areas, distribution and routing of these commodity flows and assigns them to the links of a network representing the individual transport facilities existing or proposed for the country or region under study. The performance of the system is now evaluated in detail and objective measures obtained representing several points of view. The consequences to the economy are then fed back to the macro-economic portion so that the interaction can be accounted for in subsequent time periods. This approach attempts to combine macro-economic modelling with fairly detailed simulation of the transport system over multiple time periods so that alternative development strategies, pricing policies, and investment plans may be compared and evaluated.

FA3.2 *Evaluation Procedures for Regional Transportation Planning: The Northeast Corridor Transportation Project, H. W. BRUCK *and* ROBERT T. CROW, *U.S. Department of Commerce, Washington 25, D.C.*

Evaluation of alternative planning proposals for a large, highly urbanized region such as the Northeastern seaboard of the United States raises a series of questions that go beyond the scope of benefit-cost procedures previously used for transportation planning. The problem is to improve existing techniques and to develop new ones appropriate to the examination of new transportation facilities, including new technologies, and the consequences of such facilities for regional development. The problem of devising adequate and complete evaluation techniques is further complicated by the significance at the regional level of a host of legal and policy questions. Among these are the effect of regulation on pricing in the transportation industry and the social and system benefits and costs of subsidies to some modes of transportation. Many costs and benefits relevant to regional transportation system evaluation are qualitative and difficult to compare. Thus, evaluation in terms of tangible characteristics subject to scalar measures will have to be supplemented by other techniques in such areas as urban form and environment.

FA4.1 *Applying Analytic Methods to Problems of Development Assistance, JAMES FARMER, *San Fernando Valley State College, Northridge, California.*

There are several hazards in allocating development assistance funds such as unintended distortions in infrastructures and the national economy of the recipient causing inefficient employment of the nation's resources, failure to identify the "critical investment level" for success of DA projects, and choosing a nonoptimum path to development—often the historical one. This paper gives examples of these problems and how analytic techniques can, in many cases, be useful to the decision-maker. Development assistance problems can still be characterized by difficulties in criteria formulation, data collection or derivation, and identification of resource costs. This paper describes various approaches used by others and illustrates how systems analysis and cost-benefit methods used for business and defense problems can be adapted for DA. It suggests methods adapted from economic analysis which can be used to test criteria for validity and identify the scarce resources which should be the basis for costing.

FA4.2 *Analysis of the Human Interface in Development Project Feasibility Studies, ARNOLD KENT, *Northrop Corporation, Beverly Hills, Calif., and* JOHANNES WILBERT, *University of California, Los Angeles, California.*
This paper will be presented in two parts. First, Mr. Kent will discuss briefly the nature of development systems and the implications of "analysis" at the specific project level. The impact of the human factor on project feasibility, i.e., the social science interface, is then introduced in the project feasibility study context. Various sociological factors and their impact on aspects of feasibility are examined, for projects in both the public and private sectors. In the second portion of the paper, Professor Wilbert will present four specific examples of development projects whose results were negated or impaired by events traceable directly to sociological phenomena. For each of these cases, he will outline the social science—oriented analysis that—in retrospect—would have been applicable, and would probably have spelled the difference between failure and success.

FA4.3 *Systems Analysis for Planning Infrastructure Growth in the Developing Nations, JAMES A. RAFFERTY, *Lockheed International, Los Angeles, California.*
In twenty or so of the hundred developing nations of the world, economic and social growth is paced by the ability of the economy to absorb available foreign capital. Mismatches in the rates of growth and locations of infrastructures (such as transportation, health, education, power and water resources) can unbalance the growth of parts resulting in a stagnation of the growth of the whole. Systems analysis techniques can be used to estimate balanced growth programs for the infrastructure systems of such developing nations. As an example, this paper includes a description of the design of a systems analysis of the transportation system of an African nation now in progress.

FA5.1 *A Mixed Integer Problem, C. E. LEMKE, *Rennselaer Polytechnic Institute, IBM Systems Research Fellow, 590 Madison Avenue, New York, New York.*
This paper presents a report on progress in the development of an efficient general code of the mixed integer programming problem. Past efforts and suggestions are revived in the line of the current developments.

FA5.2 *Systems of Differentiable Inequalities, MORTON SLATER, *SANDIA Corporation, Albuquerque, New Mexico.*
This paper resumes and extends a line of research of the author initiated some years ago in connection with the area now called "convex programming" and related systems.

FA5.3 *Semi-Infinite Programming, Differentiability and Geometric Programming, A. CHARNES, *Northwestern University, Evanston, Illinois,* W. W. COOPER, *Carnegie Institute of Technology, Pittsburgh, Pennyslvania, and* K. O. KORTANEK, *Cornell University, Ithaca, New York.*

The CCK duality theory of semi-infinite programming is specialized to situations involving differentiability (or partial differentiability) of objective and constraint functions to obtain in a uniform and direct manner various results and interpretations, such as generalization of the Kuhn-Tucker Theorem, the "geometric" programming of Duffin-Peterson, and the Slater constraint qualification example.

FA6 The Operational Relevance of Mathematical Programming Models for Financial Planning and Capital Budgeting, (Panel). *Session chaired by* KALMAN J. COHEN, *Carnegie Institute of Technology, Pittsburgh, Pennsylvania.*

In recent years, an increasing number of formal mathematical programming models which are alleged to be applicable to financial planning and capital budgeting problems have begun to appear in the published literature. There has, however, been much less published material discussing actual applications of these models to real-world financial and investment problems. This panel will discuss: (1) the extent to which mathematical programming models are actually being used in business firms and financial institutions as an integral part of the financial planning and capital budgeting process; (2) the degree to which the major published formal models contain theoretical shortcomings and empirical limitations which must be remedied before they can be usefully applied in practice; (3) the manner in which mathematical programming models for financial planning and capital budgeting should be integrated into the existing planning and budgeting processes of on-going corporations, with particular emphasis on the problems of (a) generating data input to the models and (b) implementing the models' recommendations; and (4) the future outlook for mathematical programming models in the finance function.

FA7.1 Long Range Satellite Systems Improvements, N. T. GRISAMORE, *The George Washington University, Washington, D.C., and* V. SELMAN, *System Sciences Corp., Falls Church, Virginia.*

The military and civilian agencies are presently faced with the dilemma of where to invest their research and development dollars in an expanding Satellite program. They may invest in improved ground length terminals and Satellite. Another alternative is allocating some portion of their budgets for improvements in the state-of-the-art for critical components which have proven themselves unreliable or exhibit low performance characteristics. The ultimate goal of the second alternative is to provide superior components which will subsequently improve their performance of satellites and satellite systems at lower over-all costs. If the Satellite program were static, straight-forward cost effectiveness and linear programming techniques could be utilized to determine the optimum allocation of funds for each alternative. However, due to the dynamics of Satellite programs, modified versions of the Von Neumann expanding economy model are used to obtain parametric solutions to hypothetical linear systems.

FA7.2 A Method of Ordering and Selecting Lunar Experiments According to Scientific Merit, E. M. Bartee, *University of Alabama, Huntsville, Alabama.*

The scientific exploration of the moon requires that a number of experiments be conducted for the purpose of investigating the many questions and hypotheses posed by nearly every discipline in the scientific community. The broad interest in this effort, the limitations of time and resources for conducting the program, and the complex engineering constraints imposed by the logistics systems justify the development of an effective method of making optimum selection of experiments according to the most meaningful criteria. The developed method provides a determination of optimum alternatives from which program authority may choose. Basic lunar scientific objectives, as determined by NASA interdisciplinary panels, serve as inputs to the system. The relative worth of each objective according to scientific merit is determined by a stratified, intradisciplinary sample of the scientific community using a modified majority-rule technique. The experiments are then ordered according to their contribution to the ordered objectives. A subjective programming method provides alternate payload choices that optimize the scientific merit of the experiments within the engineering constraints of a lunar mission. An example is presented that simulates the use of an algorithm for selecting an optimum experiment payload.

FA7.3 A Space Mission Success Evaluation Model, Robert G. Chamberlain, *Jet Propulsion Laboratory, Pasadena, California.*

High among the considerations involved in the planning of space missions is the probability of success of the mission. The determination of this probability can provide answers to such important questions as the following: 1. Is the probability of success sufficiently high to justify the planned expenditure of resources? 2. How should the currently available resources be allocated to maximize the probability of success? 3. Which of the multitude of proposed changes in design will give the greatest increase in probability of success for the least expenditure of additional resources? The approach presented shows (1) a technique for determining a quantitative measure of "success," (2) a procedure for evaluating this measure both a priori and a posteriori, (3) a systematic technique for collecting and displaying the necessary input information, and (4) a method for determining optimal allocation of resources.

FA7.4 Concepts of Investment Return in Space Program Evaluation and Comparison, J. G. Srygley, *Fort Worth Division of General Dynamics, Fort Worth, Texas.*

Program comparison methodologies which can be used as management decision tools are discussed in this paper. These methodologies aid in selecting the best program for accomplishing a particular space exploration mission. In the comparison methodologies presented, alternate space programs are treated as multiperiod investments with varying degrees of uncertainty in the mission value. Use of a discounting procedure allows the short-term gains of programs emphasizing state-of-the-art systems to be balanced against the greater long-term gains of programs emphasizing more advanced systems. In addition, when a large number of programs are compared, an indication is given as to (1) which systems should be used, (2) when each system should be developed and introduced, and (3) how long each system should be used before it is replaced. A minimax comparison methodology, which provides a method of selecting that program which is most likely to show a positive return, is developed in detail for those cases with a high degree of uncertainty in the actual mission value. Consideration is given in the minimax methodology to the rate of accumulation of the mission value, but no attempt is made to assess the total mission value. Three representative programs are compared and evaluated using the minimax comparison methodology, and a discussion is presented in which the development of program comparison methodologies is related to the overall expanding role of Operations Research in space operations.

FA7.5 The Evaluation of Space System Operational Effectiveness, W. THOMAS WEIR *and* JOHN S. YOUTCHEFF, *General Electric Company, Missile and Space Division, Philadelphia, Pennsylvania.*

The translation of a conceptual system to an operational configuration requires a specific blending of reliability, availability and performance factors. It is the purpose of this paper to consider the interelationship between reliability, availability and performance and discuss the optimum relationship of these key factors in terms of an effectiveness concept using examples from typical ballistic re-entry vehicles and space systems. To assure that reliability, availability and performance requirements are provided for in the system design, an integrated effectiveness program should be instituted and phased with equipment design and development activities. Consideration is here given to this program which should include provisions for the prediction, measurement, attainment and maintenance of system effectiveness parameters. This paper will describe the system effectiveness indices which are necessary to provide a quantitative measurement of equipment capability and program progress. The indices established for system effectiveness reporting must be developed to meet specific system and program needs. Each index chosen should be defined as an item that (1) has a significant effect on the effectiveness of the system, (2) is an established formal procedure, (3) is planned and scheduled, (4) is formally reported, and (5) is such that it can be evaluated. The broad generic grouping established for these indices are requirements, plans, analyses, and tests. These are fundamental to any program and determine the types of measurements required to provide an effective and composite availability, reliability and performability status. They should be established to cover two major information areas where measurements are required for adequate system effectiveness monitoring, evaluation and control. These are as follows: a. Equipment numeric estimates and measurements (i.e., what is the probability that the equipment will satisfy the mission requirements?). b. Program activity progress and accomplishments (i.e., how well is the program progressing relative to the assigned schedule?). These measurement indices provide complete and thorough reporting of all key information in each of the program phases of engineering design, engineering development, production and field use required for system project and program level management.

FA7.6 Optimal Location of Tracking Stations, Dennis M. Galvin, *North American Aviation, Downey, California.*

The conventional technique for predicting communication time of earth orbit missions requires simulation of the space vehicle trajectory. The time when each station is within line of sight of the vehicle is then estimated from the simulation results. This approach, although accurate and practical for short duration missions, loses its effectiveness and is economically prohibitive for missions of long duration. The analytical technique discussed exploits certain random attributes of the trajectory. These random variables are generated by observing that a large number of orbits when projected on the local geographic coordinate system are dispersed (uniformly) around the earth. The probability density function based on this hypothesis, when constrained by three mission characteristics i.e., mean orbital altitude, orbital inclination, and station location, allows prediction of the station overpass frequency of the orbiting vehicle. A transformation of the aforementioned random variables provides a means for determining the expected communication time for a given tracking station. By combining station overpass frequency with the expected communication time, a model is constructed which can be used to: 1. Locate tracking stations so as to maximize communication time for a given orbital inclination, 2. Optimize the location of tracking stations for a range of orbital inclinations, and 3. Optimize the orbital inclination for a fixed set of tracking station locations.

FA7.7 Effectiveness of Maintainable Space Systems, Glen Benz, *Daniel Mann & Mendenhall, Los Angeles, California.*

A technique for determining the effectiveness of maintainable space systems is developed and its utility in optimizing system design and maintenance planning functions is demonstrated. A summation of compound probabilities is formed as follows:

$$E=e^{-t_d/m}\sum_{r=0}^{\infty}\left[\frac{(t_d/m)^r}{r!}(1/2\pi)^{\frac{1}{2}}\int_{-\infty}^{(\log t_f-u_1-\log r)/s} e^{-y^2/2}dy\right].$$

The unconditional probability of successful operation with r outages during demand time, t_d, is determined by the Poisson law with $1/m$ as mean rate of outage occurrence. The conditional probability that the system is not out during demand time given that it has operated for this time and suffered r outages is the maintainability or the probability that the system is restored to operable condition in standby or free time, t_f. The outage time distribution is assumed log normal with u_1 and s being the normal mean and standard deviation best fitting the log normal distribution of single outages. Brief examples of how design and maintenance planning tradeoffs may be evaluated by the above effectiveness (E) equation in conjunction with cost and engineering models are given. One example is the substitution of a better wearing but more costly material in a subsystem. Another is the tradeoff between carrying certain spares in the space system versus having them dispatched from earth.

FA7.8 An Effectiveness Model for Satellite Threat Systems, H. C. SEBRING, *General Electric Company, Valley Forge Space Technology Center, Philadelphia 1, Pennsylvania.*

An analytical model is explicated for the effectiveness assessment of satellite threat systems. Some of the parameters are: number of satellite inspections per anti-satellite vehicle, kill probability, launch and payload weights, and reliability and cost factors. Multiple threat vehicles per booster are considered. One inspection is assumed to require a $\Delta\vec{V}$ of 6,000 ft./sec. for the Hohmann transfer and final velocity vector. Parametric analyses of systems performance and cost effectiveness can be made with nomograms. Tradeoff curves relate numbers of anti-satellite vehicles and numbers of orbit transfers (inspections) per vehicle. Numerical examples are presented assuming three candidate systems. The preferred system, among those assessed, is one large anti-satellite vehicle per booster launch, capable of multiple inspections. The threat model and cost effectiveness functions are considered.

FA7.9 The MINUTEMAN Weapon System Effectiveness Model, JON R. ADERHOLD, *TRW Systems, San Bernardino, California.*

Realistic tactical situations can't be produced for exercising strategic missile systems such as the MINUTEMAN ICBM weapon system, so effectiveness must be calculated analytically, using measurable secondary indicators of effectiveness such as availability, reliability, resistance to nuclear effects (survivability), accuracy, etc. This paper discusses a mathematical model and computer program developed for the MINUTEMAN Program Office to show the effects of these secondary indicators on the outcome of a dynamic two-sided nuclear exchange in which the interactions of the total strategic forces and target systems on both sides are simulated, including defenses. Effectiveness is measured in terms of forces surviving, targets destroyed, and population casualties on both sides. Proposed changes to MINUTEMAN are evaluated in terms of their impact on weapon system effectiveness in the context of this exchange, rather than on the measurable secondary indicators. Perhaps as instructive to the modern operations analyst as the model itself is the set of problems (solved with varying degrees of success) of building a model from the contributions of seven companies, five Air Force commands, one government agency, and five separate departments within the author's own company.

FA7.10 Computer Models For Missile Range Scheduling, WILLIAM C. SUHLER, *Federal Systems Center, IBM Corp., Bethesda, Maryland.*

The problem approached by this project is the generation of "optimal" conflict-free resource utilization schedules for a large missile test range. Conflict-free schedules are those in which range resources required for a test (launch, satellite read-out, etc.) are available for use. Within this framework, it is desired to optimize the range schedules using such measures of effectiveness as maximum compaction, minimization of cost, and balanced workload. The basic models used to arrive at the desired feasible schedule are a variant of the branch and comparison technique and Monte Carlo simulation. The branch and comparison model takes into consideration such items as user-desired start times (and slack times, if any), launch windows, and priorities to arrive at the most compact schedule. Requested times (or slack) are used initially to develop a primary tree whose nodes are individual subtasks of tests and whose arcs define "order" relationships among the tasks. "States" of the primary tree (sets of tasks containing all set predecessors) form nodes of the secondary tree, each node connected by an arc to a predecessor state and successor states. Construction of arcs is governed by resource requirements and the "order" relationships of the first tree. All routes through the secondary graph yield a feasible schedule and the model finds the shortest path; i.e., most compact schedule within the specified constraints. The second model, a Monte Carlo simulation, permits the introduction of stochastic contingencies. An item such as the time required by a range resource to accomplish a specific task is fixed in the branch and comparison model. Weather is not a factor in the first model. Hence, it is possible the schedule might be over-compacted, making it too sensitive to contingencies. The simulation model exercises the feasible schedule in order to measure the schedule's sensitivity. In addition to this pretest, the simulation permits measurement of resource utilization, process time, and workload balance. The necessary characteristics of actual range scheduling problems have been obtained through extensive on-site analysis of the US Air Force Eastern Test Range, Cape Kennedy, Florida.

FA7.11 Kill Probabilities for Missiles with Multiple Warheads, ALAN R. WASHBURN *and* NORMAN E. SCHILLE, *The Boeing Company, Seattle, Washington.*

When multiple warheads from the same payload are directed at their targets. the accuracy (CEP) of each warhead has both dependent and independent components. This occurs because the errors experienced prior to warhead deployment are transmitted to each warhead in the payload, and the errors experienced after warhead deployment affect each warhead individually. This report treats the development of and some results from an analytical model for calculating the distributions of point target kills resulting from the combined effects of the dependent and independent accuracy errors of multiple warheads. The model itself provides a rapid and efficient tool by which any number of targets, payloads, and warheads per payload can be considered for any combination of dependent and independent aiming errors per warhead, and for probabilities of penetration per warhead $\leqq 1.0$. In the approach used, all warheads from a given payload are assumed to be directed at separate targets. The kill probabilities for one payload are determined by numerical integration, and recursion formula is developed with which kill probabilities for more than one payload are computed. Both the dependent and independent accuracy errors are assumed to be normally distributed. Examples of typical results are presented graphically and include plots of: 1) expected numbers of targets killed, 2) probabilities of killing N out of N total targets, 3) distributions of probabilities of killing n out of N total targets and 4) combinations of dependent and independent errors which provide 90% probability of killing N targets.

FP1.1 *Introduction: The Mythography of Military R&D, ROBERT L. PERRY, *The RAND Corporation, Santa Monica, California.*

One of the least acknowledged problems of dealing with military R&D is the difficulty of distinguishing between what actually has happened and what participants or later analysts may believe to have happened in various programs. It appears that in many instances, particularly during the past 15 years, the structure and character of program management has been influenced by misconception, myth, and legend. Some examples are advanced and, as an hypothesis deserving closer examination, it is suggested that concern for formal procedures has sometimes interfered with an understanding of vital issues of R&D policy.

FP1.2 *A Critique of Cost-Effectiveness Applications to Decision-Making in Defense, KLAUS KNORR, *Woodrow Wilson School of Public and International Affairs, Princeton University, Princeton, New Jersey.*

An appreciation of the consequences of applying cost-effectiveness criteria to the R&D process is essential to an understanding of that process and to its efficient functioning. Additionally, the advantages and limitations of the cost-effectiveness approach require a full and open discussion in the context of a world environment that is changing radically and rapidly. Many considerations other than those narrowly associated with weapons effectiveness alone must be weighed in the decision process; certain of these are identified and their importance assessed.

FP1.3 *Methodological Problems in Evaluating the Effectiveness of Military Aircraft Development, THOMAS K. GLENNAN, JR., *The RAND Corporation, Santa Monica, California.*

Many efforts have been made to search out and identify the pivotal elements of cost and development efficiency in military aircraft programs of the recent past. A methodology involving discrete measurements of the several principal input resources is examined and the relevance of results to planning future programs is appraised. The question of whether qualitative measurements and analyses can be used as a base for predicting costs or development results is also considered.

FP1.4 *Problem Mongers, Solution Mongers, and Weapon Systems, PAUL J. STURM, *Office of the Director of Defense Research and Engineering, Department of Defense, Washington, 25 D.C.*

The process of planning for and scheduling the development of new systems is not readily translatable into uncomplicated diagnoses and prescriptions. One of the difficulties of maintaining a consistent system development policy over time has been that the problems and their solutions are impermanent. The required flexibility of program planning is examined and some of the pressing problems of an evolving systems development policy are analyzed.

FP2.1 *Cost-Effectiveness Criteria for Evaluating Transportation Alternatives, ALLEN V. BUTTERWORTH, *General Motors Defense Research Laboratories, Santa Barbara, California.*

Transportation is an essential element in many industrial operations. Both its cost and its effectiveness are important as criteria for evaluating transportation alternatives in particular situations. Specific examples will be given for the case of shipping automotive spare parts. In this case, effectiveness was based on total transportation time, ease of scheduling processing at origin and destination, and assurance of meeting delivery schedules. Cost included not only direct transportation cost but also the cost of restoring damaged cargo and carrying charges on inventories to protect against slow or uncertain deliveries. Techniques used in this case will be assessed for their utility in evaluating transportation alternatives in other situations.

FP2.2 *Optimization and Pricing of Traffic and Facilities, WILLIAM VICKREY, *Columbia University, New York 27, New York.*

Traffic and the land uses from which it is generated have important and complex inter-relationships and trade-offs, which when specified permit analysis of different types and sizes of city street systems. These relationships have been detailed and the resultant traffic flow and economic conditions have been simulated in order to permit optimization of the overall system and determination of appropriate pricing mechanisms. The more important aspects of this system analysis will be discussed in this paper.

FP3.1 *A Finite Renewal Algorithm for the Knapsack and Turnpike, Models, JEREMY F. SHAPIRO *and* HARVEY M. WAGNER, *Stanford University Stanford, California.*

In this paper we explore the connection between two important operations research problems. The first model, often referred to as the distribution of effort problem, is described as (1) maximize $\sum_{j=1}^{n} F_j(x_j)$, subject to (2) $\sum_{j=1}^{n} H_j(x_j) = L$ (=integer), (3) x_j non-negative integer where each $F_j(x_j)$ is real valued, each $H_j(x_j)$ is a non-negative, non-decreasing, integer valued function, and $H_j(0)=0$. The second model, which is of the renewal type, is formulated in terms of a dynamic programming recursion

$$G(L) = \underset{\substack{j=1,2,\dots,n \\ \text{and } h_j \leq L}}{\text{maximum}} \{f_j + \alpha^{h_j} G(L-h_j)\}$$

where $0 \leq \alpha \leq 1$, each f_j is a finite real number, each h_j a non-negative integer, and $h_1 = 1$. We are interested in a family of solutions corresponding to $L = 1, 2, \cdots$.

FP3.2 *Invariant Forecasters for Some Weibull Distributions, J. TIAGO DE OLIVEIRA, *University of Lisbon, Lisbon, Portugal, and* S. B. LITTAUER, *Columbia University, New York, New York.*

Given m initial observations constituting a sequence drawn from a set $X_1, \cdots, X_m$ of m independent and identically distributed random variables with the Weibull distribution (known shape parameter), a mean square invariant forecaster has been found for the expected maximum (minimum) of a set of the next N observations. When the location parameters, instead of the shape parameter, is known reduction to the Gumbel distribution is immediate and the same technique gives an invariant forecaster. The formulae, although computable, are cumbersome.

FP3.3 *The Use of Estimating Formulas in O.R., GEORGES BRIGHAM, *Arthur Andersen & Co., Seattle, Washington.*

One of the useful tools of OR consists of estimating formulas which can give approximate, but quick and reliable answers to operational questions. A particularly useful set has been developed by Robert G. Brown for estimating overall inventory requirements as a function of service level, variety, reorder frequency and sales level. This author has developed one which relates inventory requirements to machine scheduling, in the case of many products made sequentially on one of several machines, and for which change-over costs are incurred. These formulas have been found useful in estimating in advance the potential payoff from an OR study against its cost, and in answering quickly questions by management on the necessity to expand a plant. In both these cases quick, approximate answers can serve a purpose, whereas slow, accurate ones are irrelevant. Neither of these formulas, however, is good enough yet. The Brown formula assumes constant lead time and independent reordering; the author's scheduling-inventory formula assumes known demand for the product. Both theoretical improvement and practical verification are required to include the effects of additional factors. Other such general limit formulas would be extremely useful. For instance, can one estimate the profit from scheduling by linear programming, in contrast to an ordinary manual method, before it is tried out and without full-scale computations? Many similar questions have no doubt occurred to other OR scientists. Quick and reliable answers would enable them to help management make decisions better and in time. (No reprints available.)

FP3.4 *Reliability and Confidence of Multicomponent Systems, G. J. SCHICK, *University of Southern California, Los Angeles, California, and* R. J. PRIOR, *Douglas Aircraft Co., Santa Monica, California.*

The reliability and confidence of subsystems is usually fairly easy to establish by use of variable data or attribute data. Establishing the system reliability at a selected confidence level from component data at various confidence levels has been a difficult problem. The system reliability for a series system is usually given as $R_s = R_1 \cdots R_n$. In the case of a parallel system the system reliability is $R_s = 1 - (1 - R_1) \cdots (1 - R_r)$. In this paper four types of solutions to the problem of estimating the reliability and confidence of multicomponent systems are discussed: (1) Approximate solutions (2) Asymptotic solutions (3) Bayesian confidence limits (4) Exact solutions. Bayesian Statistical Models will be used to establish the confidence limits for the system reliability especially for attribute data. The underlying probability distributions selected were the Beta Function and the uniform distribution. Exact solutions proposed by Buehler, Steck, Lipow and Schick will be discussed. The use of Mellin transforms as suggested by Springer and Thompson in a recent paper for the solution of this problem will be analyzed. Several computer programs were written to find the system reliability at a specified confidence level from component data in using Mellin transforms. Several examples show how the results differ when all four of the above mentioned methods are used. An asymptotic solution to this problem by A. Madansky in the 1965 November issue of Technometrics is also discussed. This paper will summarize and compare currently available techniques.

FP4.1 *Pay-off Measures for the Allocation of Military Budgets, R. H. Blythe, Jr., *North American Air Defense Command, Ent Air Force Base, Colorado.*

PART I The comparison of active defense programs with such passive programs as blast and fallout shelters on a cost-effectiveness basis requires a payoff measure which combines the utility of people and the utility of property of all sorts. Simple utility functions are suggested and these are then combined into a measure of payoff. Some characteristics of the payoff in interesting areas are discussed. *PART II* In several new comprehensive studies of defense and offense force structures operations analysis concepts and techniques have been used in an effort to arrive at an optimum mixture of systems by a consistent, logical process. The next higher stage in the resource allocation problem is to divide resources between defensive and offensive systems. No attempt appears to have been made to apply the same analytic concepts and techniques to the solution of the higher level problems. A suitable measure of payoff which combines the utility of preserving friendly resources and destroying enemy resources is a prerequisite to future progress. Such a measure is described.

FP4.2 Military Requirements and Research Selection: Problems and Approaches, H. D. Lerner, *Applied Psychology Corporation, Arlington, Virginia, and* E. Staveley, *Office of Naval Analysis, Washington 25, D.C.*

This paper describes selected objectives, methods, and results of operations research and systems analysis conducted for the improvement of understanding and practice of research program management, with emphasis on the coordination of military requirements and research. A program of research toward the improvement of the interaction among producers and users of basic and applied research for the Navy and the Marine Corps is described. Illustrations are given of the application of operations research and systems analysis techniques to the channeling of scientific inquiry in directions which may increase the probability of achieving suitable applications. Conceptual and procedural problems involved in cataloguing military requirements, establishing their validity, and converting them into meaningful engineering and research tasks are discussed. Researchable problems and opportunities are stated for specialists in operations research and systems analysis in this field. It is suggested that increased attention be given to development of: models of research process and its management; metrics or indexes of research product value; measures of productivity, relevance, utilization, effectiveness, and efficiency of research programs; means of identifying and appraising research program control characteristics such as needs for a program, for acceleration or deceleration of effort, and for combining or segmenting programs; research methods and data for identification of conditions associated with successful research events; advanced information systems for research management; and improved means of coordinating user requirements with research.

FP4.3 Federal Support for Independent Research and Development, S. W. HENDERSON, *System Sciences Corporation, Falls Church, Virginia.*

Since World War II the Federal Government has provided more and more financial support for research and development until at the present time, it may be said that a federal research and development industry exists for the purpose of responding to such support. It must pursue research and development efforts aimed at improving its technological capacity to respond to continuously advancing governmental scientific requirements. This paper discusses present and proposed regulations aimed at allowing as much room as possible for individual and corporate ingenuity in this process; in effect encouraging research and development performances to improve their own scientific capability as work progresses. The basic concept presented in the paper and which shows much promise in this regard is that of federally supported independent research and development, otherwise known as IRND. A parallel is drawn between this and the excepted need for commercial independent research and development which improves commercial aircraft, automobile, and communications, including the cost in the price of the products. The subject of IRND is discussed as a part of the larger field of economic incentive for the conduct of research and development. Further study of these incentives particularly in relation to federal development expenditures is recommended.

FP4.4 Operations Research in Military Command and Control Systems, RICHARD L. PLOSS, *2400 North Taylor, Arlington, Virginia.*

The complex information systems that support the military command systems require a degree of integration with similar systems that is difficult to establish and even more difficult to manage. The exploitation of information processing technology by military command systems is limited by the very real problems that exist in the term "systems integration." At this time the problems affect relatively isolated systems. The problems become progressively more critical as the isolated systems are required to interface with other systems. Technology can probably meet any individual, point-to-point, data exchange requirement. Since the critical problem is complexity, the search for a practical solution must thoroughly research both the technical capabilities and the operational needs of the individual and collective users. The output is a concept of interoperability that must be capable of implementation and management. The impact of the concept on each interfaced system must be defined in both technical and operational terms. Operations Research should demonstrate that a consensus of military sponsors can be reached as to the concept of military command systems integration. This paper will amplify the above problem and explain that the military application of Operations Research must be expanded in the area of Command and Control to insure that the potential benefits of automatic data processing and data exchange are feasible.

FP4.5 A Graphical/Cost Approach to Some Weapon System Problems, E. J. ALYANAK, *The Bendix Corporation, Mishawaka, Indiana.*

A very simple cost model including major system parameters is displayed in a graphical form. In general, the approach consists of defining some end results such as "one hit on target" and then compiling the ordnance, operations and attrition cost to achieve that result. The equations are manipulated to provide meaningful terms or combinations of terms to facilitate presentation of six to eight variables on a simple graph. Such gross appraisals have been useful during conceptual design to evaluate quickly the benefits of alternatives. A particular advantage of the graphical presentation is that it provides a general rather than a specific solution. Particular problems which have been studied include (1) estimating required air defense capability, (2) exchange ratios for air defense investment, (3) comparison of mission cost for saturation, suppression or stand-off missiles, and (4) delivered weapon cost.

FP4.6 Terrain Representation Techniques in Computerized Simulation, RICHARD R. HODGES, *Logistic Studies Office, Fort Lee, Virginia.*

A number of articles have been written describing digital, analog, and player-participation methods of terrain simulation. This author has not found in any of these articles a comparative description of the representation techniques employed in these methods to reduce the real-world situation to machine usable inputs. This article describes the techniques which might be used to represent the terrain of a hypothetical war gaming problem using each of the methods named above. The description also highlights several general differences between digital and analog methods.

FP4.7 Types of Weapons Evaluation Studies Conducted by the Combat Operations Research Group (CORG) for the U.S. Army Combat Developments Command, CARLTON COMBS, JR., *Combat Operations Research Group, Fort Belvoir, Virginia.*

This paper describes the overall spectrum of weapons analyses and evaluations that are currently being conducted at HQ USACDC by the Combat Operations Group. This paper has been written to clarify the extent and relationship, one to the other, of these analyses and evaluations. Five general areas of analysis, evaluation and study are discussed and the relationships of these efforts to Army weapon system development are given. The application of weapon evaluation studies to weapon system development from the idea stage through ammunition procurement for weapons in the Army inventory is presented. This paper argues that there have evolved over the forty-odd months of USACDC's existence a definite pattern, organization and relationship of weapons evaluations. Further, it is argued that this is a logical and appropriate pattern and should be clearly understood. This paper is an effort to aid that understanding. As each area of analysis is described, a discussion of the relationships of these studies to the Army Concept Program is included and the time period of each study related to the Army Concept Program is identified.

FP4.8 Technical, Organizational, and Communicational Dimensions of Work Requirements: Development of Job Design Profiles for Engineering Departments of Navy Destroyers, MALCOLM J. CARR, *U.S. Naval Personnel Research Activity, San Diego, California.*

A conventional approach to job analysis consists of the listing of technical tasks performed in the job and the identification of a number of *worker* requirements without full assessment of requirements of the *total work situation*. The approach of this study is that a "job" is a "work position" with three major dimensions, termed the *T*echnical, the *O*rganizational, and the *C*ommunicational dimensions (TOC). An attempt is made to develop a "jog design" model according to which variables of these major dimensions can be measured and indices developed. Major Technical variables are complexity and variety; major Organizational variables are organizational position, supervision exercised and received, and work unit automony. Major Communicational variables are volume and purpose (task and non-task), scope, and status range of interpersonal contacts. The basic analytical unit is a "cluster" of men whose patterns of tasks performed exhibit a maximum degree of compositional homogeneity, as determined by a computer clustering program which generates multiple "coefficients of compositional similarity." "Cluster profiles" are developed which characterize the different clusters in terms of the TOC variables. It is expected that different occupational clusters will reveal characteristic TOC patterns. Model occupational structures will be developed in terms of the TOC variables.

FP4.9 Decision Theoretic Analysis of Requirements for Identification Information, BERNARD H. STOWENS, *Dunlap and Associates, Inc., Darien, Connecticut.*

Information about flight plans and observations of conformance with, or deviation from, these plans available at an air traffic control center can be used to help establish identity (friend or foe) of the observed aircraft. This analysis establishes the extent to which this additional information about identity is useful to an air defense command which has an individual capability for establishing identity. Statistical decision theory is used to determine optimal identity decisions and associated utilities. The value of the additional information is measured by the increase in utility resulting from the effect which this information has on the a posteriori probabilities. Among other advantages, this procedure identifies all of the pertinent factors and provides a basis for orderly consideration of their relative importance and of the relationships between them.

FP4.10 New Developments Human Factors Program, WILLIAM L. HOPKINS *Bureau of Naval Personnel, Department of the Navy, Washington, D.C.*

The Bureau of Naval Personnel is actively interested in establishing procedures which will ensure that requirements for the human element in all Navy Systems are *integral* in the planning, design, and development, as well as in the operation and maintenance of such systems. Toward this end, the New Developments Human Factors Program has been developed. This program outlines the structure, content, and gross objectives of current and planned research in the area of new developments personnel and training requirements. Personnel requirements, as a subject, lends itself to a wide variety of presentations, ranging from discussions of specific equipment or system development, to methodological creativity or improvement, to broad programs aimed at administrative and technical assurance of effective systems. The Bureau of Naval Personnel, within its assigned mission, deals with personnel requirements at each of these levels. Within the time alloted, each of these will be discussed to an extent which will suggest the Bureau's role in the development and maintenance of a personnel requirements research program. Specific research will be mentioned dealing with a Personnel Simulation Model, the Corrective Maintenance Burden Prediction Procedure, and the impact of microelectronics on training.

FP4.11 Site Security—Some Qualitative Considerations, G. R. Desl. *Westinghouse Electric Corporation, Electronics Division, Baltimore 3, Maryland.*

Given a number of military installations and military force charged with protecting these installations from undesirable activities (e.g. sabotage or espionage) by intruders. The problem is to determine the distribution of manpower, transportation, automatic detection means, natural or man-made hazards or deterrents, communications between sensors and the military force, information processing, and response of the force which will most effectively provide protection to the site at a given cost. Alternatively, the problem may be phrased to provide a given amount of protection at minimum cost. While this problem has all the ingredients of a (rather complex) mathematical optimization problem, certain fundamental concepts must be examined and agreed upon. This paper deals primarily with arriving at some concepts which have meaning in the real-life problem and which lend themselves to workable, if not entirely unambiguous, definitions. Most systems to which formal analysis is applied, have identifiable parameters, variable within certain limits. Intrusion threats, on the other hand, intelligently seek out and capitalize on a system's weaknesses by means of a vast variety of actions limited only by human imagination to conceive plans and human skill to execute them. Definition of the threat (i.e. what constitutes an intrusion?) must be based on innovated plans which are feasible, against the particular system, taking into account other surveillance systems and security procedures with which the site in question will be associated. Once a set of threats is generated, it becomes possible to define such concepts as "Detection Volume" and "Security" with respect to the generated set.

FP5.1 *Solution Methods for Chance Constrained Programming, Gifford H. Symonds, *Box 222, Rocky Hill, New Jersey.*

The chance constrained model of stochastic programming has been formalized and some general solution methods are proposed. The chance constrained model is defined as a problem with the following characteristics: Select x to maximize a function $z(x)$, or $z(x,\alpha)$ subject to probability constraints of the form $Pr(y(x) \leqq 0) \geqq \alpha$, where $y(x)$ is a random vector for each given vector x, and α is a given probability. If $y(x) = Ax - b$, where matrix A and vector b contain random variables, then the problem is a stochastic linear programming problem. The probability

α is related to the loss function in the two-stage model. In the chance constrained model, α may be selected by: (1) policy, (2) independent optimization, (3) parametric evaluation, or, (4) included in the objective function. Each chance constrained problem has an associated certainty problem as follows: Select x and $y^k(x)$ to maximize $z(x)$, or $z(x,\alpha)$ subject to certainty equivalent constraints corresponding to each probability constraint $y^k(x) \leqq 0$, and $F_x(y^k(x)) = \alpha$, where $y^k(x)$ is a vector of constants within the range of the random variables in $y(x)$ for each x, and $F_x(\ )$ is the distribution function of $y(x)$. It is shown that an optimal solution of the certainty equivalent problem is also an optimal solution of the stochastic programming problem for both linear and nonlinear problems. By application of Lagrangean methods and Kuhn-Tucker theory, general solution methods are developed for several types of problem formulation.

FP5.2 Primal Decomposition Methods for Structured Linear Programming Problems, Edwin V. W. Zschau, *Stanford University, Stanford, California.*

This paper describes an approach for solving in a decentralized fashion linear programming problems whose matrices exhibit either block-diagonal or staircase structures or some combination of the two. The heart of the approach is to formulate the structured linear problem as a very simple concave programming problem. The optimality conditions for this non-linear problem suggest a decomposition algorithm for solving the linear one which has considerable intuitive appeal. This algorithm is primal feasible in the sense that on every iteration each subproblem solution is feasible with respect to all constraints of the complete problem. In addition, for block-diagonal problems, the algorithm may be interpreted as a model of the dynamic adjustment process to achieve equilibrium in a competitive market. The paper includes a summary of computational experience for problems of various structures and sizes.

FP5.3 Change-Constrained Generalized Networks, A. Charnes, *Northwestern University,* M. Kirby, *University of Chicago, Chicago 37, Illinois, and* W. Raike, *Northwestern University, Evanston, Illinois.*

An extension to the theory of linear programming over generalized networks is presented which replaces the generalized Kirchoff node conditions by chance constraints. The extension is motivated by a class of problems in sanitary and chemical engineering in which the non-zero entries in the generalized incidence matrix may be random variables. Duality relationships are established for appropriate pairs of such chance-constrained programming problems by showing that their deterministic equivalents consist of a deterministic generalized network problem and its dual. It is also shown how these duality relationships may be exploited in order to obtain actual solutions to chance-constrained generalized network problems.

FP5.4 A Simplified Decomposition Technique for Large Angular Linear Programs, P. M. Ghare, *Texas Technological College, Lubbock, Texas.*

This paper presents a simplified technique for the decomposition of a particular class of large linear programs. In the terminology used by Dantzig and Wolfe, these are the angular programs. In this technique the interconnecting program is decoupled into small programs which, along with the subprograms, form new auxiliary subprograms. The resource vector is allocated amongst these auxiliary subprograms. The solution algorithm then consists of iterations of the type a) solutions of auxiliary subprograms, and b) improvement of the allocation of resource vector. The iterative process converges to the optimal solution. The requirement of core memory is reduced to the size required for the largest of the auxiliary subprograms which would be usually smaller than that required for solving the interconnecting program.

FP5.5 Bivalent Nonlinear Programming, PETRU L. IVANESCU *and* SERGIU RUDEANU, *Institute of Mathematics, Romanian Academy, 47, Eminescu Street, Bucharest, Romania.*

A procedure is proposed for solving problems of nonlinear programming, the variables $x_1,\cdots,x_n$ of which can take on only the values 0 and 1. The procedure is based on two techniques: 1. Minimization of unconstrained functions with bivalent variables. This procedure is based on a combination of dynamic programming with Boolean computation. It is a recursive procedure giving in $n+1$ steps both the minimal value, and all the minimizing points of the function. 2. Determination of a Boolean function (the "characteristic function of the constraints") which takes the value 1 for those and only those values of the variables, which fulfill the constraints. The characteristic function determines a complete set of families of solutions to the constraints. For each family of solutions we determine, by means of the technique indicated at 1, those solutions contained in the family which realize the smallest value of the objective function. In this way the initial problem is transformed into that of minimizing many unrestricted functions with bivalent variables. We select afterwards the minimizing points. An alternative approach is the following: determine the characteristic function of the constraints as in 2, and introduce it by means of a Lagrange-multiplier-type technique into the objective function; minimize now the so-obtained unrestricted function with bivalent arguments, as in 1. The procedure has been used until now only for hand computation, and the results are very satisfactory; its programming for a MECIPT-1 computer is in progress.

FP5.6 Bivalent Hyperbolic Programming, PETRU L. IVANESCU, *Institute of Mathematics, Romanian Academy, 47, Eminescu Street, Bucharest, Romania.*

The importance of programming problems with a fractional objective function was pointed out by Charnes, Cooper, Dinkelbach, Martos. Here a procedure is proposed for solving mathematical (linear or nonlinear) programs with fractional objective functions, and with bivalent (0, 1) variables. Among the practical applications we mention that of determining that development program of an enterprise which realizes the smallest production costs. The proposed procedure uses a combination of dynamic programming with Boolean computations.

FP5.7 Pivot Rules in Linear Programming, VICTOR KLEE, *University of Washington, Seattle, Washington.*

In the solution of linear programming problems by means of the simplex algorithm, many different pivot rules have been employed. The computational experience of Kuhn and Quandt (Operations Res. 12(1964)161–165) suggests that if the efficiency of a rule is measured by the *average* number of iterations required for problems of a given size, then the usual pivot rule (which at each step maximizes the gradient in the space of nonbasic variables) is definitely less efficient than the rule which at each step calls for the greatest improvement in the objective function. Some recent mathematical results lead to the same comparison for the *maximum* number of iterations which may be required. For nondegenerate problems having as feasible region a convex polytope of dimension $n-m$, determined by m linear equality constraints in n nonnegative variables, the usual pivot rule may require as many as $m(n-m-1)+1$ iterations in order to reach the optimal vertex and may pass through all the other vertices on the way. By contrast, the second rule requires at most m iterations if $m=n-2$, at most $[3m/2]$ if $m=n-3$, and appears to require at most $2m-1$ when $m \leqq n-4$. Though neither of the numbers $m(n-m-1)+1$ nor $2m-1$ has been definitely established as the maximum in question, the comparison between the two numbers is suggestive.

FP5.8 On the Convex Hull of a Finite Set, CHRISTOPH WITZGALL, *National Bureau of Standards, Washington, D.C.*

Let S be a finite set in m-space. We consider the problem of finding the vertices and edges of the convex hull $H(S)$ of S. The problem of finding the vertices has applications in Statistics and Control Theory. It has been studied by Goldstein. He describes an algorithm which besides finding the vertices of $H(S)$ also determines its $(m-1)$-dimensional faces if such exist. Even a moderate number of inequalities, however, is apt to generate a huge number of $(m-1)$-dimensional faces. Hence the problem of finding all these faces is inherently difficult. Therefore two algorithms are proposed which find the vertices of any convex hull $H(S)$, but avoid finding its $(m-1)$-dimensional faces. It is hoped that these algorithms require less work than the algorithm proposed by Goldstein, since the latter solves a harder problem. In addition, an algorithm for finding the edges of a convex hull $H(S)$ is described. This algorithm, too, avoids finding all $(m-1)$-dimensional faces. All proposed algorithms are based on the simplex method. Experiences with computer codes are discussed.

FP5.9 On Solving Bi-Criterion Mathematical Programs, ARTHUR M. GEOFFRION, *University of California, Los Angeles 24, California.*

It often happens in applications of mathematical programming that there are two incommensurate objective functions to be extremized, rather than just one. One thus encounters bi-criterion programs of the form $\text{Maximize}_{x\epsilon X} h(f_1(x), f_2(x))$, where $h(\cdot,\cdot)$ is a (nonlinear) increasing utility indicator function defined on pairs of outcomes of the concave objective functions f_1 and f_2, and x is a decision n-vector constrained to the convex set X. In this paper it is shown how such programs can be numerically solved if a parametric programming algorithm is available for the parametric sub-problem

$$\text{Maximize}_{x\epsilon X}\ \alpha f_1(x) + (1-\alpha) f_2(x),\ 0 \leqq \alpha \leqq 1.$$

Thus when the parametric sub-problem is a parametric linear program, for example, the nonlinear (and perhaps even non-concave) bi-criterion program can be solved by a simple modification of a stock parametric linear programming routine. An inherent advantage of this approach is that it yields as a by-product a relevant portion of the tradeoff curve between f_1 and f_2. When h is quasiconcave, as is usually the case, the parametric sub-problem need only be solved on a subset of the unit interval. Some extensions are presented.

FP5.10 The Tank Assignment Problem, LAWRENCE BRISKIN, *The Carborundum Company, Niagara Falls, New York.*

The problem of scheduling tankers involves among others the problem of determining an optimal tank assignment at the tanker terminals. This paper considers a multi-product system with tanks of various sizes. The problem is to determine which tanks should be used to store the respective products at the tanker terminals. The problem is formulated as a goal linear program. However, since only one product may be stored in a given tank at a given time, the problem is ultimately one of goal integer linear programming. The problem formulation and solution is applicable to a wide variety of situations such as storage of materials which may not be mixed in bins of various sizes.

FP6.1 *The Role of Operations Research in Corporate Long-Range Planning with Respect to Programs for R&D, Education and Career Development, THOMAS E. OBERBECK, *Office of Research Analyses (OAR), Holloman AFB, New Mexico.*

An earlier paper has established a homomorph (augmented mathematical model) of the long-range planning process within a corporate organization such as a military department or large industrial firm. The validity of this homomorph as a representation of the long-range planning process is now substantiated with empirical evidence concerning the planning procedures of thirteen large corporations as reported in *Managerial Long-Range Planning*, edited by G. A. Steiner (McGraw-Hill, 1963). In this paper, the homomorph is used to identify, first, the R&D programs, education programs, and career development programs of contemporary industrial and military organizations as activities of operating departments, and second, the requirement to clarify organizational objectives and goals with respect to such programs. The role of operations research in relating such programs to objectives and goals as a part of the long-range planning process is described. An historical analogue is developed with respect to the introduction of accounting as an integrating function of organizations aimed at enhancing over-all efficiency. A concept of an educational function of future industrial organizations is defined in terms which permit the operations research group concerned with the corporate long-range planning process to identify this function as a component of manpower utilization. Finally, the considerations for improving the efficiency of the educational function within the organizational environment are argued as a potential stimulus for applications of advanced technological development to the general educational process.

FP6.2* The Effects of Perceived Needs and Means on the Generation of Ideas for Industrial R and D Projects, NORMAN R. BAKER, *Purdue University, Lafayette, Indiana,* A. H. RUBENSTEIN, *and* JACK SIEGMAN, *Northwestern University, Evanston, Illinois.*

A flow model is constructed which identifies some of the organizational factors influencing idea generation behavior in industrial R and D laboratories. The model is constructed from literature-based propositions which make explicit the role played by the organizational factors identified in the model. Data were collected on nearly 300 ideas created in a divisional laboratory of a major U.S. corporation. In general, these data support the a priori propositions. Further, data analysis suggests that two pieces of information are required before an idea is generated: 1) Knowledge of a *need,* problem, or opportunity relevant to the company; and, 2) Knowledge of a *means* or technique for satisfying the need, solving the problem, or capitalizing on the opportunity. These results are discussed with respect to the stages of creative thought proposed by other investigators. Finally, the organizational events, which were associated as "needs" events or "means" events for the ideas studied, are identified and analyzed with respect to both quantity and quality of ideas.

FP6.3 Reprogramming Analysis for R&D and Other Activities, MARK ALFANDARY-ALEXANDER, *U.S. Atomic Energy Commission, Washington 25, D.C.*

A program planning and control method is presented in terms of a multi-period micro-input/output analysis of R&D activities, in contradistinction to several approaches which focus entirely on the input analysis, usually for a single period. The measurement of program accomplishments is made through the observation of objective entities; the constrained extremization of the program is done by means of a combination of objective data and subjective concepts. The subjective constructs are Bayesian-type utilities, whose logical and empirical justifications are given. The control aspects of the program plan follow naturally from the design. Evaluation of alternative strategies is carried out so that the ratios of the outcome ratings are dimensionless numbers. A common space is developed for the participating outcomes, which is proportional to the importance of the values. These values are then used in the constrained extremization which yields the normative policy vector required for any set of periods in the planning horizon.

FP6.4 Cost-Effectiveness in Research and Development: Observations on a Case Study, HANS J. LAUE, *Stanford Research Institute, Menlo Park, California.*

The application of a cost-effectiveness study to a research and development program for the instrumentation of military field experiments is presented. Various general conclusions on cost-effectiveness models are drawn from the case study. Difficulties in defining quantifiable effectiveness criteria compatible with the missions are overcome by selecting suitable nonquantifiable criteria, allowing at least an ordering of the alternatives. It is submitted that an ordering both for effectiveness and for cost of alternatives is a sufficient condition for obtaining a set of efficient solutions. The concept of a set of solutions "efficient in probability" is defined to account for uncertainties in cost or effectiveness. A game-theory approach is used to find optimal solutions under conditions of uncertain delivery dates.

FP6.5 Truncation and End-Effect Corrections for Long Range Planning Models,

W. P. Drews *and* L. A. Rapoport, *Esso Research and Engineering Company, Florham Park, New Jersey.*

It is generally recognized that long-range planning models should encompass a sufficient time span to account for the lasting effects of investments and other major commitments. This, then, calls for large "dynamic" L.P. formulations, describing explicitly a number of successive time-periods. However, for purposes of practical computation, such dynamic formulations must be "truncated" i.e., confined to the representation of only the first few periods. In turn, this can cause distortions or errors in the planning solution. In this paper it is attempted to develop a compromise between the analytical rigor of large, "dynamic" planning models and the computational attractiveness of small, truncated formulations. The presented material examines the properties of certain broad classes of dynamic models and deals generally with the relationships which may be asserted between the truncated and untruncated dynamic model solutions. More specifically, it deals with the definition and discussion of "end-effect corrections" which may be used to obtain undistorted (or least distorted) solutions by means of practical, truncated models.

FP6.6 The Optimization of an Already-Scheduled Packaging Program,

B. Gentry Lee, *Martin Company, Denver, Colorado.*

This paper considers the optimization of a packaging program whose delivery schedule is given a priori. The mathematical model developed in this paper was specifically designed to handle an Air Force space-experiment packaging program, but the method employed has application to a general class of schedule problems. It is assumed that a nonlinear programming analysis has determined the way in which N objects are to be placed in P packages. Both the objects and the packages arrive at a service point 0 with arrival distributions that may or may not be known. The objects are placed in the appropriate packages according to a given servicing distribution. A package is "delivered" when all the objects slated for that package have been serviced. The optimization of this process involves the minimization of an objective function—called the penalty function in this paper—that assesses penalties for those occurrences that might be construed as increasing the cost (or any desired parameter) of overall system operation. In this particular model, a linear penalty function is chosen and penalties are assessed for missing the prescribed delivery schedule, for servicing delays, and for bottlenecks in queues. After these penalties have been expressed mathematically, a simple deterministic example is calculated to illustrate both the computational complexity and the flexibility of the model. It is stressed that the specific equations and mathematical analysis given in this paper are not intended to serve more than a small set of operational systems; however, the general method of penalty function analysis is applicable to a variety of realistic problems.

FP6.7 Paraphysical Variables in Weapon System Analysis, IRVING CASEY, *Analytic Services Inc., 5613 Leesburg Pike, Falls Church, Virginia.*

The effectiveness of a weapon system is dependent not only upon its physical characteristics but also upon the social characteristics of the enemy. The reaction of enemy combatants to attack is a function of personality, culture, and social organization. In order to obtain from a weapon system the results theoretically possible, these paraphysical variables must be considered. If the paraphysical effects of weapons are to be exploited, they must be expressed in a form which is usable in weapon system analysis. To accomplish this objective, it is proposed that the concept of model personality be employed as a construct in the study of overt combat behavior to generate the basic data needed.

FP6.8 A Minimum Risk Manpower Scheduling Technique, ROGER F. JEWETT, *Lockheed-California Company, Burbank, California.*

A manpower scheduling technique is developed for the uncertain workload case. The workload or demand for manpower during the scheduling period is defined by a finite set of possibilities, each of which is considered. A Dynamic Programming formulation is derived to determine a Minimum Cost schedule for each workload and a Minimum Risk schedule is developed for the set of requirements. The Minimum Risk objective is discussed and computational advantages over Minimum Expected Cost are outlined. Linear cost functions and discrete probabilities are used and several operational aspects of the approach are mentioned. This technique is well suited to problems with a limited number of uncertain events and cases where an assumed distribution of random events is unrealistic.

FP6.9 A Model of a Budgetary System's Ways of Influence, GÖRAN WIDEBÄCK, *University of Lund, Lund, Sweden, and Center for Research in Management Science, University of California, Berkeley, California.*

The purpose of this conceptual model is to be a basis for description of different budgetary systems, perhaps even for designing of budgetary systems. The model is limited to the planning phase of the budgeting. In the model budgeting is considered as a problem-solving process governed by the budgetary system, which may be considered as a problem-solving program. The problem of the ways of influence of a budgetary system may be divided into two parts: (1) How a budgetary system becomes a program for the budgeting people (management and staff) in an organization. Program is here considered as a set of instructions. (2) How a budgetary system, considered as a program, affects the design of the budgetary planning process and the output of the process, the budget. For the first part of the problem the explanation must apparently be of behavioral nature. The model emphasizes the exposition of some information elements by the budgetary systems in a situation where the management can perceive and process a very limited amount of information only. The presence of convenient elements of a problem-solving language is focused also. In the second part of the problem the given, the budgetary system, and the wanted, the planning process, are considered as problem-solving programs. The core will be transformations from one type of description to another. In the model, the basis for the transformations is first the property "programmed" in the budgetary planning and second a division of the problem-solving process in three parts, statement of the problem, generation of solutions, and evaluation of solutions. Statement of the problem is here connected with the aggregating of the separate decision variables to a particular decision structure.

FP7.1 *Leviathan Research: Recent Findings and Next-Generation Models, BEATRICE *and* SYDNEY ROME, *System Development Corporation, Santa Monica, California.*

Over the past few years, the Leviathan project has been developing a method for studying control and policy making in large organizations. The method comprises a theoretical framework, a system of computer programs, a series of experimental simulations in a laboratory, a repertory of experimental controls, and quantitative measurements of organizational performance. In an experimental run, 20 to 30 subject-executives meet for eight to twelve hours each week, over three-month periods, and interact with each other and with hundreds of robots through a computer that operates on line and in real time. The computer carries out the policies of the executives, and furnishes each with knowledge of technological accomplishments according to his level of command, functional specialization and territorial authority. Experimental objectives are to determine interrelationships between (1) executive policy formation, decision making, and control and (2) system performance of the simulated organizations, within (3) experimentally controlled organizational environments. Findings in the present laboratory and the resultant new Leviathan simulation capabilities (to be realized in a new laboratory supported by an IBM 360-67 system) will be reported.

FP7.2 Problems in Simulating Communications Networks, BERNARD BACKHAUT, *Transportation and Communications Service, General Services Administration, 18th and F Streets, N.W., Washington, D.C.*

The author of the paper has participated during the past four years in the development of communication network simulations of the PACCS and NORAD networks for the Air Force and the AUTOVON and AUTODIN networks for the Defense Communications Agency. He is presently engaged in efforts to develop for the General Services Administration computer simulations of the Federal Telecommunications System and the Advance Record System, the government civilian voice and data networks. The paper groups the problems in developing communication network simulations into ten categories: (1) determination of objectives, (2) data collection, (3) approximations, (4) technique selection, (5) programming, (6) validation, (7) statistics, (8) network synthesis and optimization, (9) generalization of results, (10) special networks. Each of these ten categories is discussed in detail. The author then describes how these problems have been resolved in the simulations in which he has participated. The paper concludes with a discussion of the problems in communication network simulation which still require further research.

FP7.3 Optimum Forcing of a Telephone Company Business Office, K. S. USUI *and* L. M. SCHUMANN, *The Southern New England Telephone Company, New Haven, Connecticut.*

A stochastic demand-server model, programmed in both SIMSCRIPT and GPSS III, is used to simulate the operation of a telephone business office. Functional specialization of personnel is incorporated although this is optional. Input to the model includes negative exponential interarrival rates and service times for various types of contacts with any statistical distribution (e.g. exponential, normal, empirical, etc.) permitted. Several levels of priority in work assignment are also included. Productivity statistics by function and quality of service data are produced as outputs. Sensitivity analysis experiments conducted with this model led to the construction of a deterministic model. The deterministic model, programmed in Fortran IV, also calculates productivity and quality of service statistics with incoming calls arriving according to a Poisson distribution. Results show that productivity in a business office is a function of the size of the office, its proportion of clerical work, the percentage of incoming calls encountering a busy condition, and the manner in which incoming volumes vary during the period studied. These relationships are qualified. The construction of two models—the stochastic model and the deterministic model—allows mutual validation. Both models are completely generalized so that they may be used in analyzing a wide variety of business office or other demand-server functions.

FP7.4 A Heuristic Approach to Routing Telephone Traffic, R. C. CARLSON, *Bell Telephone Laboratories, Holmdel, New Jersey,* K. S. USUI *and* R. G. MAHER, *The Southern New England Telephone Company, New Haven, Connecticut.*

The problem of routing at minimum cost subscriber calls to a telephone business office is discussed in this paper. Linear and dynamic programming approaches were investigated but neither could be used since certain underlying prerequisites, e.g. linearity, optimality at successive stages, are not present. A trial and error approach was also infeasible since the solution set varies from 7^{10} to 7^{122}, depending upon the number of business offices. Accordingly, a heuristic method was devised and programmed in Fortran IV. In a simplified way, the steps in the heuristic approach are (1) compute for *all* existing routes cost savings realized from using an existing route instead of establishing a new direct route to the business office; (2) select the existing route affording the greatest savings and put it on the routing list; (3) recompute the savings on all remaining routes given that the route selected in step (2) has eliminated some routes and effected the realizable savings on others; (4) repeat steps (2) and (3) until all remaining existing routes result in negative savings, at which time the existing routes are rejected and traffic is routed directly to the business office. This heuristic approach has produced results which constitute a highly satisfactory routing pattern.

FP7.5 The Feasibility of Automated Trust Administration, WILLIAM D. GRIFFIN, *HRB-Singer, Inc., P.O. Box 60, State College, Pennsylvania.*

The administrative aspects of investment activities require certain quantitative information concerning particular investments and the analysis of combinations of investments. Trust administration also involves decision making and appropriate documentation. This paper is concerned with the first two functions: quantitative information on investments, and analysis of combinations of investments (portfolios). The information that is used in performing these two functions may be ummarized to obtain certain status reports and tax reports as a useful indirect utput. The feasibility of automated trust administration is based on expected ains which offset the costs. The automation consists of extensive but routine omputations of expected returns from investments activities, and mathematical rogramming of the set of activities comprising a portfolio. Both of these functions are described. An example of the analysis to be employed is included in the orm of a real estate investment. This analysis takes into account alternatives in he method of capitalization and in the method of depreciation, along with the ther factors of the venture. A linear programming approach is then used to ptimize the allocation of investment funds over the various investment opporunities. The results are shown in the form of a cost-effectiveness function that akes into account size of the trust department.

FP7.6 Simulation Models in Marketing, HAROLD WEITZ, *IBM Corporation Yorktown Heights, New York.*

The reasons why the application of scientific methods to marketing problems has een slower than their application to other areas lie principally in the complex ature of the marketing environment. In developing a market strategy, the marketing manager must contend with: nonlinear relationships, time lags and decay characteristics, complex market mixes, varying states of the market, environmental conditions, and competitive maneuvers. Relatively little is known about the likely impact of a marketing decision. Mathematical models frequently are too simple to portray complex dynamic market processes; and consequently, such models offer little guidance to the market strategist. To solve these problems, simulation offers a unique opportunity. This paper discusses: a) the elements of the consumer market mix problem, b) the limited benefits of normative and statistical models, c) some of the more recent marketing simulation models—their characteristics and strengths, d) the relative advantages of simulation, e) a conceptual framework for a generalized marketing model, and f) future directions for simulation applications in marketing.

FP7.7 Concepts for Simulating Management Strategies as Applied to a Maintenance Parts Logistics Environment, S. FIELDEN, *IBM Corporation, Poughkeepsie, New York.*

Many concepts are involved in bridging the gap between a management strategy in an actual environment and a computer simulation of that strategy and environment. These concepts are vital to the specification of maintenance parts logistics models. Among the concepts described are: *Control for conflicting systems.* An automatic initial spare parts distribution system must not impact the inventory control system. *The state of knowledge, or "accidental spying" in a model.* It is necessary because of delays in information flow, to prevent the use, prior to the appropriate time, of data for decision making. *Prescreening of variables. Measurements. Defining management strategies. Decisions and decision responsibility. The validation problem.* What criteria should be used to validate a simulation model, and what should the designer do to achieve acceptance? *Input requirements and assumptions. Sequencing transactions.* Is bias introduced by fixing the order in which inventory transactions occur within the model? Oversight or casual treatment of these potential problem areas can cause a model to yield misleading information or to be rejected by the ultimate user as "not representative of rea life."

FP7.8 An Evaluation of the MILITRAN Programming Languages, KENNETH WIGLER, *Naval Command Systems Support Activity, Washington Navy Yard, Washington, D.C.*

The MILITRAN language is evaluated as a vehicle for the expression and computer implementation of military simulation models. Areas of evaluation include ease of model definition, programmer/analyst aids, debugging time, and overall effectiveness. The evaluation is based upon a comparison of FORTRAN and MILITRAN implementations of a model to investigate sealift capabilities and attrition in an ASW environment.

FP7.9 An Analyst's View of MILITRAN, THOMAS GIAMMO, *Systems Research Group, Inc., 1501 Franklin Avenue, Mineola, New York.*

MILITRAN is a simulation-oriented, general purpose computer language developed by Systems Research Group, Inc. under the sponsorship of the Office of Naval Research. The primary purposes of MILITRAN are: (1) to facilitate the design of a simulation model to be implemented on a digital computer, (2) to reduce the time and expense necessary to program the simulation model, and (3) to assist in the extraction of meaningful results from the simulation. The MILITRAN simulation language is described from the viewpoint of an analyst designing a digital simulation. A general systematic approach is developed in regard to the design of such simulations and a point for point correspondence of this methodology with specific MILITRAN features is made.

FP7.10 An Information Retrieval System for a Small Operations Research Group, PIERRE M. TULLIER *and* THOMAS W. MASON, *The Franklin Institute, Center for Naval Analyses, Arlington, Virginia.*

An information retrieval system has been developed for the Marine Corps Operations Analysis Group of the Franklin Institute's Center for Naval Analyses which may be of interest to other small operations research groups. The system design has stressed simplicity with a small number of descriptors and minimum requirements for personnel. In operation of the system, a large volume of classified information is scanned by the group's analysts and only those items pertinent to operations research on Marine Corps problems are filtered out. Each document is then tagged with the descriptors which attempt to capture essential elements of the paper. The descriptors are drawn from groupings of things, places, operational functions, organizations, physical phenomena, values, processes, environments, and performances. The title of each document, source, security classification, year of publication, descriptors, and various accession numbers including the Defense Documentation Center's (DDC) accession number are put into computer storage. Monthly accession bulletins are produced for the research staff and individual requests for information are processed to retrieve documents and to produce bibliographies on demand.

FP7.11 Computer Information Retrieval and R&E Management, JOSEPH J. MAGNINO, JR., *IBM Corporation, P.O. Box 218, Yorktown Heights, New York.*

Research and Engineering management have common problems in complexity, multiplicity, reporting, feedback evaluation, interrelationships and decisional requirements. Managers also require similar basic facts when monitoring large scale R&E operations; these being concise and current project descriptions, budgets, manpower, and schedules. Recognizing these determinants, the IBM Corporate Staff developed and implemented a computerized information retrieval system to provide a meaningful procedure in acquiring, storing, maintaining, and using these necessary basic facts. This Automated Project File system has been tested and in operation for over five years and employs a computerized normal text information retrieval system to avoid the usual classification problems inherent in research and engineering projects, and yet provide management with selected reports of only those projects with the data required. Detailed descriptions of the system characteristics, the input documents, methodology, I.R. capabilities, and the use by management and the line engineer or scientist, as well as the services provided by the IBM Technical Information Retrieval Center, are discussed with specific examples. A center satellite mode of operation with teleprocessing capability services all the R&E Laboratories of IBM in the United States and in Europe, and is briefly described.

Society Affairs

THE ORSA COUNCIL MEETING

The Twenty-Eighth Meeting of the Council of the Operations Research Society of America was held on 3 November 1965, prior to the ORSA meeting in Houston, Texas, with GEORGE SHORTLEY, *President*, presiding. The following items from the Council Meeting are reported:

FUTURE ORSA MEETINGS:

No.	Dates	Location	Chairman
29	May 18–20, 1966	Los Angeles	JOHN E. WALSH *System Development Corp.* *2500 Colorado Avenue* *Santa Monica, Calif. 90406*
30	October 17–19, 1966	Durham, N.C.	GEORGE E. NICHOLSON, JR. *Department of Statistics* *University of North Carolina* *Chapel Hill, N.C. 27515*
31	May 31–June 2, 1967	New York	GORDON D. SHELLARD *New York Life Insurance Co.* *51 Madison Avenue* *New York, New York 10010*
32	November 1–3, 1967	Chicago	T. E. CAYWOOD *Peat, Marwick, Caywood, Schiller & Company* *401 N. Michigan Avenue* *Chicago, Illinois 60611*
33	Spring 1968	San Francisco	F. L. WELDON *3410 Kettering Court* *San Mateo, California*
34	Fall 1968	Philadelphia	LEO ROGIN *Air Warfare Research Department* *NADC* *Johnsville, Pennsylvania*

ORSA MEMBERSHIP: As of 18 October 1965, there were 1697 *Members*, 2725 *Associate Members*, and 435 *Student Associate Members*, for a total membership of 4,856.

IFORS: Plans for the Fourth International Conference on OR are progressing. It is scheduled to take place in Cambridge, Massachusetts August 29–September 2, 1966.

AAAS: The 1966 meeting of the AAAS will be held on the East Coast, and another session schedule will be prepared for that meeting.

ORSA-MORS: The MORS Spring 1966 meeting in Monterey has been scheduled to precede the ORSA May 1966 meeting so that people can attend both MORS and ORSA conveniently.

SECTIONS COMMITTEE: The Council recognized the inactive status of the Management Operations Research Society (Central New York); unless it becomes active again, the Council will declare it dissolved at its next meeting.

Transportation Science Section was commended for its recent activities, including a very successful International Transportation Science Symposium.

LANCHESTER PRIZE: The Lanchester prize was awarded to F. M. Scherer, for "THE WEAPONS ACQUISITION PROCESS: ECONOMIC INCENTIVES."

NOMINATIONS: The following slate has been announced by the Nominating Committee (biographies and ballots are being mailed to the Membership separately):

Vice-President (President-elect)	Leslie C. Edie
	John E. Walsh
Secretary	Joseph H. Engel
Treasurer	Thomas E. Oberbeck
Council Members (2)	Walter L. Deemer
	James C. Hetrick
	George E. Nicholson, Jr.
	Gordon D. Shellard

(In addition, as a result of nomination by petition, George W. Morgenthaler has been nominated as a candidate for *Council Member*.)

PUBLICATIONS COMMITTEE: The Council agreed that the Publications Committee is justified in pursuing a more aggressive policy in relation to the Publications in Operations Research series.

EDUCATION COMMITTEE: From March 30 to April 2, 1966, the Education Committee of ORSA and the American Council for Education, will sponsor a joint conference at Johns Hopkins University, to discuss mutual problems. The Education Committee is planning to revise and re-issue the bulletin on education programs.

MEETINGS COMMITTEE: Concern was voiced over the presentation at recent ORSA meetings of papers previously presented elsewhere, and the appointing of session chairmen who are not ORSA Members. While both these practices were deplored, no official action was taken. Meeting chairmen will be reminded informally of accepted practice on these matters.

MAILING LIST: The Council authorized an expenditure to accomplish the change-over from the present method of maintaining the Society mailing list to a more sophisticated system.

It was the sense of the Council that the Secretary and Business Manager should use the mailing list to advance the goals of the Society.

PRESIDENT'S ADVISORY STAFF ON SCIENTIFIC INFORMATION MANAGEMENT (PASSIM): The Council agreed to support with enthusiasm, House Joint Resolution 666 to provide for the establishment of an agency in the Executive Office of the President to be known as the Presidential Advisory Staff on Scientific Information Management (PASSIM).

NEW MEMBERS: The Membership Committee reported its nominees for full Membership in the Society. A list of new Members is shown:

Elected Members at 28th National Meeting

Aderhold, Jon R.
Adomian, George
Andersen, Sigurd L.
Anderson, Richard L.
Baldwin, Woodson William
Banerjee, Ranajit
Barrar, Richard Blaine
Bartlett, Dwight Kellogg
Barton, Richard Fleming
Bowers, Robert Dana
Brown, David E.
Buchanan, William Barclay
Buckley, Douglas John
Buys, Robert Myron
Choisser, Robert William
Cook, Kenneth S.
Dalton, Robert Edgar
Davis, Edward Alex
Dear, Robert Ernest
Deodati, Joseph B.
DeQuoy, Alfred Warren
Dimon, George H., Jr.
Dugan, John F.
Dunlap, Duane Sherbert
Edison, James Allen
Flueckiger, Wallace D.
Furth, Enrique
Gardner, Charles William
Grace, George J.
Grace, H. David
Green, Ralph J., Jr.
Gregory, Lowell D.
Grossman, Harry
Gue, Ronald L.
Haight, Frank A.
Harvey, Laurence A.
Haymond, Phillip M.
Heselton, Leslie Richmond, Jr.
Hogan, Edward T.
Hubbard, Robert L.
Jamieson, Derek Maitland
Johnson, Charles R.
Kapper, Francis B.
Kleinrock, Leonard
Kornfeld, Jack Paul
Krieger, Stuart A.
Kruck, Frederick H.
Langdon, John G.
Laumets, Endel
Laureyns, George A.
LeVasseur, Paul Michael
Linsenmeyer, Roy Forest
Lockerd, John A.
Martino, Joseph Paul
Means, Edward Hector
Miller, Jack M.
Mirsky, Robert
Morton, Anton S.
Mowery, Vincent O.
Pessemier, Edgar Allen
Phillips, Harry C.
Pipes, Louis Albert
Randazzo, Frank Paul
Seidman, David R.
Selogie, Louis A.
Sheehan, John K.
Smallwood, Richard D.
Staadt, (Mrs.) Mary Adelle
Tharp, Gerald G.
Usui, Kenneth S.
Vaughan, Elizabeth
Warren, Richard L.
Weinberger, Frank Maury
Weindling, Joachim L.
Williams, Jacob Alberry
Willis, John Gibson
Wythe, Donald
Zamanakos, Arthur S.
Zeitlin, Eli A.

Joseph H. Engel
Secretary

WESTERN SECTION OF ORSA

The *Secretary* of the Society has been informed that the Chairman of the Western Section of ORSA, Harvey M. Wagner, announced the results of their election for officers, which are:

Chairman	Herbert Solomon
Vice Chairman	Arthur C. Christman, Jr.
Secretary/Treasurer	Lloyd D. Yates

ERRATA

The 1965–66 Directory of ORSA inadvertently listed the following persons as *Associate Members* rather than *Members* of the Society. Each is a full *Member*: C. Richard Cryer, David Freund, Irving Katz, Marvin Rothstein and Lawrence F. Young.

Charles E. Bradley (M), 5 Carderock Court, Bethesda, Md. (George Washington Univ.) was omitted. Richard Ray Hodges was omitted from the geographical listing. The correct affiliation for Herbert S. Millstein is Management Technology, Inc. The affiliation of Roger A. Ahrens, 215 Broadmere Drive, Florissant, Missouri 63033, should be McDonnell Automation Center.

TREASURER'S REPORT

Holloman AFB, New Mexico
February 17, 1966

Following is a statement of Cash Receipts and Disbursements of ORSA for the calendar year 1965. The report of the auditors accompanies this statement. A breakdown into two columns is used, with International Abstracts in Operations Research receiving special consideration. The method of statement is on an explicit cash basis with major obligations listed by note.

Thomas E. Oberbeck
Treasurer

Baltimore, Maryland
February 18, 1966

AUDITORS REPORT

The Operations Research Society of America,
Baltimore, Maryland.

We have examined the statement of cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1965. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

In our opinion, the accompanying statement presents fairly the cash receipts and disbursements of The Operations Research Society of America for the year ended December 31, 1965.

Lybrand, Ross Bros. & Montgomery

STATEMENT OF CASH RECEIPTS AND DISBURSEMENTS

For the year ended December 31, 1965

	Regular	*International Abstracts in OR*
Receipts:		
Members' dues	$54 691	$13 328
Subscriptions	41 525	19 629
Advertising, less commissions	17 289	
Sales of back issues	5 308	1 404
Interest	3 830	
Third International Symposium, net of $16,049 expenses	3 701	
Royalties	2 720	
Meetings, net	1 006	
Mail list, net	225	
Miscellaneous	220	
	130 515	34 361
Disbursements, as annexed	86 474	33 537
Excess of receipts over disbursements	44 041	824
Cash at beginning of year	81 470	16 204
Cash at end of year	$125 511	$17 028
Represented by:		
Petty cash funds	700	275
Demand deposits	8 652	16 753
Deposits with federal savings and loan associations and bank	116 159	
	$125 511	$17 028
Portions of the cash balance are reserved as follows:		
Unearned subscriptions:		
Volume 14 (OR) to be issued in 1966	42 000	
Volume 6 (IAOR) to be issued in 1966		8 000
Guarantee to publisher of the Society's series "Publications in Operations Research"	6 000	
Third International Symposium	5 700	
IFORS dues for 1965	1 600	
Unpaid reimbursement vouchers and bills	1 000	500
	$56 300	$8 500

DISBURSEMENTS

For the year ended December 31, 1965

	Regular	*International Abstracts in OR*
Journal printing costs	$43 784	$24 600
Editorial and other expenses	9 614	2 287
Salaries and fees		3 798
Managerial services	20 445	2 069
Bulletin printing	4 073	
Printing and binding directory	4 075	
Travel expense		242
Council and officers' expenses (Note)	136	
General society expenses	1 732	
Lanchester prize	1 000	
Supplies, materials, etc.		541
Auditing	300	
Committee expenses (Note)	289	
Sections expenses (Note)	959	
Miscellaneous	67	
Total disbursements	$86 474	$33 537

Note: Details of council and officers' expenses and committee expenses are:

Council and officers' expenses:

President	$34
Vice-President	—
Secretary	94
Treasurer	8
	$136

Committee expenses:

Membership	$47
Prize	197
Nominating	45
	$289

Sections expenses:

Military applications	$588
Transportation science	276
Cost effectiveness	95
	$959

REPORT OF THE EDUCATION COMMITTEE

The Education Committee, in collaboration with the American Council on Education, will meet at The Johns Hopkins University, May 11, 12 and 13. Interested OR program directors are invited to join the Committee for the first day, which will be devoted entirely to matters of Operations Research Education. A summary of the evolution and status of formal offerings in OR, level of development of course material, and trends in enrollment will be presented.

The Committee is preparing a new bulletin on formal programs in Operations Research. Forms have been sent to institutions known to have such offerings. Program directors who have not received forms should write the Committee Chairman in order to be included.

The Committee receives inquiries for summer programs in OR. It will assist in answering these if sponsors of short courses will inform the Committee of their programs.

Information for the Education Committee should be sent to Charles D. Flagle, Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland 21218.

News and Announcements

DURHAM (CHAPEL HILL) NATIONAL MEETING OF ORSA

The 30th National Meeting of ORSA will be held at the Jack Tar Hotel in Durham, North Carolina during October 17–19, 1966. GEORGE E. NICHOLSON of the University of North Carolina is Meeting Chairman and WALTER L. DEEMER of the U.S. Arms Control and Disarmament Agency is Program Chairman. Panels and paper sessions are being organized by the Technical Sections of ORSA. Submission of contributed papers is encouraged.

June 1, 1966, is the deadline for contributed papers (abstracts of 200 words or less), which are to be sent to GEORGES BRIGHAM, *Arthru Anderson and Co., 501 Norton Bldg., Seattle, Washington 98104.*

WESTERN NATIONAL MEETING OF MORS

The 17th Classified Military Operations Research Symposium (MORS), sponsored by the Office of Naval Research, will be held May 23–25, 1966, at the US Naval Post Graduate School at Monterey, California. The theme is The Role of Operations Research in Matching Operational Capability to Military Requirements. These dates have been selected to make it easier for people to attend both the MORS and the ORSA meeting to be held the previous week in Santa Monica. Further information can be obtained from Mr. Vance R. Wanner, Executive Secretary, Military Operations Research Symposia, Old Post Office Building, 12th Street and Pennsylvania Avenue, North West, Washington, D.C.

INTERNATIONAL FEDERATION OF OPERATIONAL RESEARCH SOCIETIES 1966 CONFERENCE

The Fourth International Conference on O.R. will take place at the Massachusetts Institute of Technology, Cambridge, Massachusetts, U.S.A., from August 29th to September 2nd, 1966. (The closing date for submission of papers was November, 1965.)

As the *Bulletin* went to press, the following sessions and their chairmen were available to the Editor:

1. ADVANCES IN TECHNIQUES OF MATHEMATICAL PROGRAMMING
   MONSIEUR JEAN ABADIE, *Direction des Etudes et Recherches, Electricite de France, 12 Place des Etats-Unis, Paris XVI, France*
2. ADVANCES IN TECHNIQUES OF DECISION THEORY
   PROFESSOR HOWARD RAIFFA, *Harvard Business School, 16 N. Harvard Street, Allston, Massachusetts, U.S.A.*
3. ADVANCES IN TECHNIQUES OF STOCHIASTIC MODELING
   DR. GEORGE KIMBALL, *Arthur D. Little Inc., 35 Acorn Park, Cambridge 39, Massachusetts, U.S.A.*

4. THEORY OF GRAPHY
   SIGNOR CLÁUDE BERGE, *Centre International de Calcul, Palazzo delli Uffizi, sona dell'Eur, Rome, Italy.*
5. MARKETING
   DR. JOHN D. C. LITTLE, *Massachusetts Institute of Technology, Alfred P. Sloan School of Management, 50 Memorial Drive, Cambridge, Mass. 02139, U.S.A.*
6. TRANSPORTATION
   MR. E. C. WILLAIMS, *Chief Scientific Advisor, Ministry of Transport, St. Christopher House, Southwark Street, London S.E.1.*,
7. URBAN PLANNING
   DR. RUSSELL L. ACKOFF, *Director, Management Science Center, Wharton School of Finance & Commerce, University of Pennsylvania, Philadelphia, Pennsylvania 19104, U.S.A.*
8. INVESTMENT POLICY ANALYSES
   MONSIEUR JACQUES LESOURNE, *S.E.M.A., 35 Boulevard Brune, Paris XIV, France.*
9. SCHEDULING PROBLEMS
   PROFESSOR DR. H. P. KÜNZI, *Rechenzentrum der Universität, Ramistrasse 71, Zürich, Switzerland.*
10. INFORMATION PROCESSING
    HERR KRISTEN NYGAARD, *Söndre Flaskebekk, Nesoddtangen, Norway.*
11. SIMULATION
    DR. K. D. TOCHER, *United Steel Companies Ltd., Cybor House, 1–5 Tapton House Road, Sheffield 10.*
12. NATURAL RESOURCES
    DR. GIFFORD H. SYMONDS, *Box 222, Rocky Hill, New Jersey 08553, U.S.A.*
13. DISTRIBUTION SYSTEMS
    DR. SAMUEL EILON, *Imperial College of Science & Technology, Department of Mechanical Engineering Building, Exhibition Road, London S.W.7.*
14. GENERAL CONTRIBUTED PAPERS
    DR. WILLIAM S. JEWELL, *c/o M. Pierre Rosenstiehl, G.E.M.P.P.S., Ecole Pratique de Hautes Etudes, 17 Rue Richer, Paris IX, France.*

Registration information for this meeting may be obtained from: Hugh J. Miser, Travelers Research Center, Inc., 250 Constitution Plaza, Hartford, Connecticut 06103. Fee of $90 (includes preprints, bound Proceedings, lunches, reception, and Wednesday dinner) required with application.

NATO/APOR CONFERENCE

The NATO Advisory Panel on Operation Research is organizing under the aegis of the Science Committee, a *Conference on the Design and Analysis of Field Experiments*. It will be held at *Consiglio Nazionale delle Ricerche, Piazzale delle Scienze, 7, Rome, Italy,* May 23–27, 1966. The Conference Director is K. L. YUDOWITCH, Data Dynamics, Inc., 1625 Eye Street, N.W., Suite 1026, Washington, D.C., U.S.A., and the Administrative Director of the Conference is CAPT. D. MUSCOLINO, *State Maggiore Difesa, Consiglio Tecnico Scientifico, Via Luigi Rizzo, 28, Rome.* Applications should be made to CAPT. MUSCOLINO at the address above.

CANADIAN OPERATIONAL RESEARCH SOCIETY (CORS)

The Eighth Annual Conference of the Canadian Operational Research Society will be held at McGill University, Montreal the 12–13 May, 1966 Further information may be obtained from: J. Gratwick, *Conference Committee Chairman, C.N.R., P.O. Box 8100, Montreal 3, Canada.*

JOINT ECONOMETRIC SOCIETY AND TIMS MEETING (WARSAW)

The European Meeting of the Econometric Society and TIMS will be held in Warsaw from 2nd to 7th September, 1966 (2nd and 3rd for ES; 5th: Joint Session, 6th and 7th for TIMS.

The Chairmen for ES are:

General Chairman: H. Wold (University of Uppsala, Sweden)

Program Chairman: T. Sargan (The London School of Economics, London) and W. Sadowski (Central School of Planning and Statistics, Warsaw, Poland).

The Chairmen for TIMS are:

General Chairman: J. Abadie (Electricité de France, Paris, France)

Program Chairmen: H. Künzi (University of Zürich, Rämistrasse 71, Zürich, Switzerland), and W. Sadowski (address above).

The local organizing Committee is headed by K. Romaniuk, Central School of Planning and Statistics, Warsaw, and I. Epsztejn, Institute of Economics and Organization of Industry, Warsaw.

Papers of interest in the fields of Econometrics, Scientific Management, Planning and Programming are expected. Abstracts for consideration from 300 to 500 words should be received in two copies by one of the Program Chairmen before 1st March 1966.

The full text of accepted papers to be presented to the conference must be received by the Program Chairman before 1st August (15th of May for those who wish to have their papers reproduced). Authors reproducing their own papers are requested to bring with them 200 copies.

Further information can be obtained from the Secretary of the Congress: G. Rupinski, *Instytut Ekonomiki I Organizacji Przemyslu, Plac 3-ch Krzyzy 3/5, Warsaw, Poland-Post Box 153—Cable address: Inekop.*

INTERNATIONAL COMPUTATION CENTER (ROME)

An International Symposium on Mathematical Methods in the Social Sciences will be held in Rome from July 4 to July 8, 1966 under the auspices of the International Computation Centre—F. Braudel (Collège de France), B. de Finetti (University of Rome), G. Th. Guilbaud (E.P.H.E.), P. F. Lazarsfeld (Columbia University), C. Lévi-Strauss (Collège de France) and J. Piaget (University of Geneva) have graciously consented to be Honorary Members of the Symposium.

The Congress will be divided into four sections. Each section will consist of an invited address (one hour), a number of comments on submitted papers (fifteen to thirty minutes) and general discussion (half hour).

The four sections with their chairmen are: *Anthropology:* P. MARANDA, *Archaeology:* J. C. GARDIN, *Psychology:* C. FLAMENT, *Sociology:* R. BOUDON.

The Proceedings of the Congress will contain invited lectures, the contributions to the symposia, and the program of the Congress. They will be available by October 1966. Only papers which have been submitted to the Organizing Committee in their final version by May 1966 will be included.

The official languages of the Symposium are French and English with simultaneous translation.

The participation fee for membership in the Congress is $25. Please make checks or bank drafts payable to the "International Computation Centre—Symposium Social Sciences" Banca Nazionale del Lavoro, Agenzia 18, Viale C. Colombo, 550, E.U.R., Rome, Italy, and submit them together with the enclosed registration form by May 31st, 1966 to the International Computation Centre, 23, Viale Civiltà del Lavoro E.U.R., Rome, Italy.

A number of social events will take place during the Symposium. These include excursions to the mediterranean beaches and archaeological sites in the Rome area and a banquet on Friday night. Furthermore this Symposium will be followed by a Seminar on Graph Theory.

The seminar on Graph Theory will be held in Rome, from July 8–12, 1966 under the auspices of the International Computation Centre, Rome. The seminar will consist of invited lectures as well as contributed papers. The seminar follows immediately after an International Symposium on Mathematical and Computational Methods in Social Sciences described in the accompanying announcement. Interested persons who wish to present a paper should submit an abstract of the paper to the chairman of the Program Committee: P. C. GILMORE, Thomas J. Watson Research Center, Box 218, Yorktown Heights, New York, U.S.A.

Abstracts should not exceed two pages. They may be written in French, German or English and should reach the chairman before March 1, 1966.

For further information contact the *International Computation Centre, P.O. Box 10053, Rome E.U.R., Italy.*

INSTITUTO DE INVESTIGACIONES ESTADISTICAS

The following announcement has been received from J. M. GARCIA of the *Instituto de Investigaciones Estadisticas, Serrano 123, Madrid 6, Spain.*

On November 24th, 1965, the Institute of Statistical Research concluded "Course II on Operations Research" for Latin-Americans. This Course was organized by the Institute of Statistical Research in collaboration with the Institute of Spanish Culture and the Organization of American States. The number of fellowship holders was 16.

This Course was held from November to February, 1965 and consists of seminars on theoretical and practical aspects, visits to various firms, performance of research projects, etc., under the direction of the Director and Professors of the Institute. The sessions were full-time, and the program of subject matter was the following: Mathematics, Theory of Probability, Mathematical Programming, Theory of Games, Industrial Statistics, Industrial Economics, Sampling Techniques, Theory of Estimation, Stochastic Processes, Time Series, Econometrics Seminar of Operations Research.

The Institute of Statistical Research of the Spanish Higher Council of Scientific Research, in collaboration with the Spanish-French Association of Technical and Scientific Cooperation held a Colloquium from October 13th to 15th, 1965 on the subject: "Operations Research in Economic Development."

This Colloquium consisted of four sessions:

I. Operations Research at the National Level.
II. Operations Research at the Local and Regional Level.
III. Operations Research at the Level of the Industrial Firm.
IV. Applications of Operations Research in Diverse Fields.

In these sessions Spanish and French Researchers presented communications and exchanged experiences.

OPERATIONAL RESEARCH SOCIETY

The Operational Research Society, London, has scheduled a number of Meetings and Study Groups for the coming year, and regularly maintains a registry of University and other course offerings as well as professional openings in the United Kingdom. Inquiries should be directed to Mrs. Margaret Kinnaird, *Operational Research Society, 64 Cannon Street, London, E.C. 4.*

George A. Yewdall, *Ealing Technical College, St. Mary's Road, London W.5,* has noted that the ORSA Cost-Effectiveness Section is similar to the Financial Effectiveness Study Group of the Operational Research Society and invites ORSA members who may be in England to attend those sessions.

J. Crank, *Department of Mathematics, Brunel College, Woodlands Avenue, Acton W.3,* draws attention of readers to a *Symposium on Simulation Techniques and Languages* to be held at the College on May 10–11, 1966. This two-day session first treats basic simulation techniques, then turns to general simulation languages, such as G.S.P., SIMSCRIPT, C.S.L.II, SIMULA, E.S.P., SIMON, and AS.

ARGENTINE CENTER

The Institute for Mathematical Techniques Applied to Management (*Centro de Investigación de Técnicas Mathemáticas Aplicadas a la Dirección de Empresas*), CITMADE, a non profit organization, was created in April, 1963, sponsored by the National Institute of Industrial Technology (I.N.T.I.) to investigate and promote the use of Operations Research, Statistics, and Computation in Management. For further information, write Ing. Fermin A. Bernasconi, *Executive Secretary, CITMADE, Cerrito 1139—2° piso, Buenos Aires, Argentina.*

LARGE SCALE PUBLIC EDP SYSTEM CONFERENCE

A conference on this subject was held April 1–2, 1966, at the Barbizon-Plaza Hotel, New York, New York. Herman Berkman, Graduate School of Public Administration, New York University, was *Conference Chairman.* The purpose of the conference was to focus attention on both the broad and specific administrative aspects and implications of information processing functions in large scale public systems which serve multi-purpose needs on the State and Local level. Concurrent section meetings were held on Educational Systems, Police and Judicial Systems, Urban and Regional Planning Systems, Public Health and Hospital Systems, Welfare and Employment Security Systems, Governmental Management

Systems, and Special Public Systems. For more information, address Doris Martin, *Office of Special Projects and Conferences, Division of General Education, New York University, 12 West 4th Street, New York, New York 10003.*

AAAS MEETING

A Joint ORSA-TIMS program was presented at the AAAS annual meeting in Berkeley, California, Wednesday, December 29, 1965. Topics included a morning session on *Computers and Universities*, chaired by Ralph W. Gerard, and an afternoon session, *State of the Art and the Prospects for Data Gathering, Storage, Transformation, and Retrieval*, chaired by J. C. R. Licklinder. For further information: Burton V. Dean, *Case Institute of Technology, Cleveland, Ohio.*

HUMAN FACTORS IN ELECTRONICS

The Seventh Symposium on Human Factors in Electronics of the Institute of Electrical and Electronics Engineers will be held at the Radisson Hotel, Minneapolis, Minnesota, May 5–6, 1966. For further information, write K. Scott Foster, *Publicity Chairman, Seventh Symposium on Human Factors in Electronics, The Institute of Electrical and Electronic Engineers, 345 East 47th Street, New York, New York 10017.*

NATO GRADUATE APPRENTICESHIPS

In 1962 the NATO Science Committee initiated a program of graduate apprenticeships in operations research. Under this program young scientists may be assigned for "on the job" training in operations research to one of a number of NATO or national centers. The normal assignment is for two years. Each apprentice receives from NATO funds an allotment of $4,000 per year together with his travel expenses to and from home and place of work. Applicants must be citizens of one of the NATO nations, must have a first degree in mathematics, engineering, physics, chemistry, or economics. Applications are received by December 31st of the year preceding the September in which the applicant would like to begin his apprenticeship. After that date, applications may have to be deferred to the following year. For further information and application: *Assistant Secretary General for Scientific Affairs, North Atlantic Treaty Organization, Place du Maréchal de Lattre de Tassigny, Paris, XVIe, France.*

FELLOWSHIPS AND RESEARCH IN MATHEMATICS

The Division of Mathematics, National Academy of Sciences–National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418, publishes a brochure entitled *Fellowship and Research Opportunities in Mathematics*, available at the address above, which lists opportunities available through many government agencies from the Areospace Research Laboratories to the Weather Bureau. Other sources of financial support are given in the bulletin, *A Selected List of Major Fellowship Opportunities and Aids to Advanced Education*, also available from the National Academy of Sciences–National Research Council, at the address above. These documents are revised periodically, and provide a current survey of fellowship and post graduate possibilities in the government.

CENTER FOR INDUSTRIAL DEVELOPMENT (UNITED NATIONS)

The Center for Industrial Development, United Nations, announces an expansion of its efforts and the consequent need for Economic Affairs Officers and Industrial Development Officers. Activities include research and overall planning for both small-scale and large-scale industries, continuing review of technological developments, technological and economic analyses, feasibility studies, and analyses pertaining to the adoption of specific processes and equipment. Requirements include a university degree, in engineering and at least three years experience in industry. Preference is given to those who have contacts among professional, academic, and business circles in specific fields or industries, and who have previous experience in promoting cooperation at a national and international level. Fluency in English is required, knowledge of French or Spanish desirable. Salary scales range from $7234 to $16,412, *after taxes*. Dependency allowances of $300 per dependent child and $400 for spouse are also provided, as are other benefits. For further information: W. H. Tarzi, *Secretariat Recruitment Service, Office of Personnel, United Nations, New York, New York, 10017.*

M.I.T. SUMMER PROGRAMS

The Massachusetts Institute of Technology offers four short courses for the summer, 1966, as follows:

July 5–July 15	*Introduction to Probabilistic Systems*
July 25–August 5	*Design and Analysis of Scientific Experiments*
August 22–August 26	*On-Line Computation and Simulation*
September 5–September 9	*Operations Research in Public Affairs*

Probabilistic Systems, the first offering, assumes a knowledge of second year calculus. The other courses have been designed without this assumption.

The *On-Line Computation and Simulation* offering will provide instruction in the on-line OPS system, developed at M.I.T.'s Project MAC, which enables the user at a remote terminal of a time-shared computer to build and test a simulation model incrementally, make matrix computations symbolically, perform a variety of statistical analyses, and custom-design his own information-processing operators. The program will examine questions of simulation strategy which become important when model construction and running are interactive.

For further information on these programs: *Director of the Summer Session, Room E19-356, M.I.T., Cambridge, Massachusetts 02139.*

UNIVERSITY OF MICHIGAN SUMMER COURSES

The University of Michigan announces the following courses for the summer, 1966:

May 31–June 10	*Applications of Computers in Hospitals*
July 11–July 22	*Fundamental Concepts in Probability and Random Processes with Applications*
July 25–July 29	*Topics in Military Operations Research*
August 8–18	*Quality Control by Statistical Methods*

August 8–19	*Recent Mathematical Advances in Operations Research and Management Sciences*
August 8–19	*Foundations and Tools for Operations Research and the Management Sciences*

For further information, write: *Engineering Summer Conferences, West Engineering Building, The University of Michigan, Ann Arbor, Michigan.*

SOUTHERN STATISTICS COURSES

A brochure containing a list of the Summer 1966 Graduate Course offerings in statistics at Southern Universities may be obtained by writing the *Southern Regional Education Board, 130 Sixth Street, N.W., Atlanta, Georgia.* The Universities participating in this offering are Clemson, Emory, Florida State, Georgia Tech, Johns Hopkins, Mississippi State, North Carolina State, Oklahoma State, Southern Methodist, Texas A&M, University of Alabama, University of Florida, University of Georgia, University of Kentucky, University of North Carolina at Chapel Hill, University of Tennessee, University of Texas, Vanderbilt, and Virginia Polytechnic Institute. The brochure lists courses available at each of these institutions.

OPERATIONS RESEARCH PROGRAM AT KANSAS UNIVERSITY

The School of Business, University of Kansas, announces a program leading to the degree of Master of Science in Business with a concentration in Operations Research.

The program builds on an undergraduate degree in business and offers at the graduate level the following new courses:

Introduction to Operations Research
Mathematical Programming for Business
Advanced Techniques in Operations Research
Seminar in Operations Research

Each Operations Research candidate for the Master of Science in Business is required to conduct an O. R. study in an actual business firm. Students have full access to the University's Computation Center facilities, which, in February, 1965, will include a GE-625 computer with on-line time-sharing capabilities. For further information: RICHARD F. BARTON, *School of Business, The University of Kansas, Lawrence, Kansas 66045.*

THE UNIVERSITY OF ARIZONA

The Systems Engineering Department of the University of Arizona, Tuscon, Arizona, is now offering a Ph.D. program in Systems Engineering. Students holding an M.S. degree may be admitted to this program by passing a qualifying examination which requires a broad background in probability and statistics, engineering mathematics, numerical analysis and computers, optimization and operations research, human factors, and systems theory. Students may also enter with a bachelor's degree and participate in a Master's program which insures their proficiency in the six areas above. Thesis and dissertation subjects are chosen according to the interest of the student in one of these fields of knowledge.

Faculty members of the Department of Systems Engineering with their areas of research interest are, to date:

S. R. Browning,	programming systems,
L. Duckstein,	optimization and traffic flow theory,
J. W. Perry,	non-numerical applications of computers and information retrieval,
J. L. Sanders,	operations research and stochastic processes,
E. W. Titt,	numerical analysis,
H. Tucker,	applied probability and statistics,
R. J. Weldon,	human factors,
A. W. Wymore,	(Head of the Department), systems theory.

In addition to the Numerical Analysis Laboratory, (which is the computing center for the University), the Systems Engineering Department supports and administers a Human Factors Laboratory, a Systems Laboratory and a Statistical Laboratory.

For additional information, write *Department of Systems Engineering, The University of Arizona, Tuscon, Arizona 85721.* (A brochure is available.)

CORNELL UNIVERSITY

On July 1, 1965, Cornell University established an intercollege Department of Computer Science in the Colleges of Engineering and Arts and Sciences. To aid the creation of this department and further its growth the Alfred P. Sloan Foundation has awarded Cornell University a grant of one million dollars.

The new department already has a faculty of seven: R. W. Conway, J. Hartmanis (*Chairman*) R. J. Walker, P. C. Fischer, G. Salton, C. Pottle and S. Saltzman. In addition to the staff of the Department the graduate field of computer science at Cornell University includes H. D. Block (Mechanics), C. F. Hockett (Linguistics), W. L. Maxwell (Operations Research), A. Nerode and L. E. Payne (Mathematics), and S. Searle (Statistics). The fields of study and research now represented include programming languages and systems, numerical analysis, data processing and information retrieval, and automata theory and theory of computation.

The Department of Computer Science is authorized to grant the Ph.D. and M.S. degrees in Computer Science.

Further information: J. Hartmanis, *Department of Computer Science, Upson Hall, Cornell University, Ithaca, New York.*

SHORTER NOTICES

The following programs, although completed at the time we go to press, may be of historical interest to readers of the *Bulletin.*

The University of California at Los Angeles held a conference on *Computer Graphics, Utility, Production, Art,* April 4–6, 1966. Topics included computer applications in the graphic arts, printing and publishing, and other forms of graphic computer input/output devices including software. The program was sponsored by the *University of California Extension Services, University of California, Los Angeles 90024.*

The New York Chapter of the American Statistical Association in cooperation with the Public Health Association of New York City held a *First Annual Conference on Simulation in Business and Public Health, Theory and Practice,* March 2–3, 1966. Topics ranged from Production Scheduling and Inventory Control, Marketing and Advertising, and Decision Problems in Business Enterprise to Simulation in Public Administration, Hospital Administration and Medical Care, and Information Dissemination and Retrieval in Medicine and Public Health. For further information: CLAIRE HARING, *D'Arcy Advertising Co., 430 Park Avenue, New York, New York.*

The New York Metropolitan Section of the Association for Computing Machinery (ACM) held a symposium on *The Applications of Computers to the Problems of a Metropolitan Society,* in New York City, March 18, 1966. At this meeting both computer specialists and administrative officials, including speakers MAYOR JOHN V. LINDSEY and TRAFFIC COMMISSIONER HENRY A. BARNES, directed their attention to such topics as "Computers, Pricing Mechanisms, and Optimum Traffic Transit Patterns," (WILLIAM S. VICKERY, *Columbia University*), "A Quantitative Approach to Urban Law Enforcement Problems," (ROBERT B. SHUMATE, *Systems Science Corporation, Bloomington, Indiana*), and "The Impact on Business Organizations of Communications-Oriented Data Processing Centers," (ROBERT A. LEONARD, *I.T.T. Data Services, Paramus, New Jersey*).

The *Fifth International Teletraffic Congress* (On the Application of The Theory of Probability to Telecommunication Research, Engineering and Administration) will be held in New York June 14–20, 1966. For further information: Secretary of the Organizing Committee, ITC Congress, Room 2G-525, Bell Telephone Laboratories, Holmdel, New Jersey.

Case Institute of Technology is conducting a short course on Recent Developments in Operations Research, June 1–3, 1966. Write BURTON V. DEAN, Chairman, Operations Research Group, Case Institute of Technology, Cleveland, Ohio.

Rutgers—The State University, New Brunswick, New Jersey, will hold a course on Operations Research in Industry, May 23–27, 1966, and a course on Computers and Engineering Applications, June 20–24, 1966. Write ANTHONY J. DEL MASTRO, Director, Center for Continuing Engineering Studies, Rutgers—The State University, University Heights, New Brunswick, New Jersey 98903.

PERSONAL ITEMS

CHARLES EDWIN CLARK, senior scientist at System Development Corporation, Santa Monica, California, died at his home, 609 Twentieth Street, June 16, 1965, after a long illness. With SDC six years, DR. CLARK was a specialist in the mathematical and statistical problems of Monte Carlo Methods, who had previously been a consultant at Booz, Allen, and Hamilton in Chicago, The Operations Research Office, and the Ballistics Research Laboratory, Aberdeen. The author of five volumes on mathematics and statistics, and numerous articles on Operations Research, he was an originator of PERT and had taught mathematics at Emory University, Purdue, and the University of Rochester. He was a member of Phi Beta Kappa, Sigma Xi, American Mathematical Society, Mathematical Association of America, and ORSA, and is survived by his wife, GWENDOLYN A., daughters, Mrs. Larry E. Westphal, Cambridge, Massachusetts, and Miss Vicky Clark, and son Charles E., Jr. at home, and his mother and two sisters, who reside in Rochester, New York, his birthplace.

Richard Bellman has been appointed Professor of Mathematics, Medicine, and Engineering by the University of Southern California, University Park, Los Angeles.

Hugh J. Miser has joined the staff of the Travelers Research Center, Inc , Hartford, Connecticut, as Vice President and Director of the Department of Environmental Systems Management Studies.

Andrew Vazsonyi has been appointed Scientific Advisor for management planning at North American Aviation, Inc., El Segundo, California.

Narahari U. Prabhu has joined the staff of Cornell University as Associate Professor.

Allan E. Paull has joined the staff of the University of Toronto, Toronto 5, Canada, as Professor of Statistics jointly in the School of Business and the Department of Mathematics.

Roger L. Sisson has been appointed Associate Professor of Operations Research and Industry in the Warton School of Commerce and Finance, University of Pennsylvania.

Clay H. Hollister has retired from Ernst & Ernst, Cleveland, Ohio, and has taken an assignment to conduct a program on Internal Financial Controls for the Council for Internal Progress in Management. The assignment is on Okinawa for ten weeks.

Irwin W. Kabak has joined the faculty of the Graduate School of Business Administration of New York University.

Charles D. W. Thornton has been promoted to technical assistant to the director of operations staffs at the world headquarters of International Telephone and Telegraph Corporation, New York City.

Robert G. Dick has been promoted to biostatistician in the department of science information and computer application, Mead Johnson Research Center, Evansville, Indiana.

Lloyd D. Yates has been promoted to associate technical director, Matson Research Corporation, San Francisco, California. Eric E. Sorensen has been named to Yates' former post as manager of physical systems.

Robert T. Livingston received the Gilbreth Medal of the Society for the Advancement of Management, October 15, 1965.

Martin N. Chase has been appointed Vice President of Washington Area Activities by Technical Operations Research, Arlington, Virginia.

Donald G. Malcom has received the "Distinguished Alumnus Award" of Purdue University.

Charles W. Missler has been appointed manager of computer applications in the Ford Research and Engineering Center, Dearborn, Michigan.

Joel N. Bloom and Arno Cassel of the Franklin Institute have been appointed to serve on the Highway Safety Committee of the Highway Research Board of the National Academy of Sciences–National Research Council.

George W. Rathjens, Jr., has been appointed Director of the Weapons

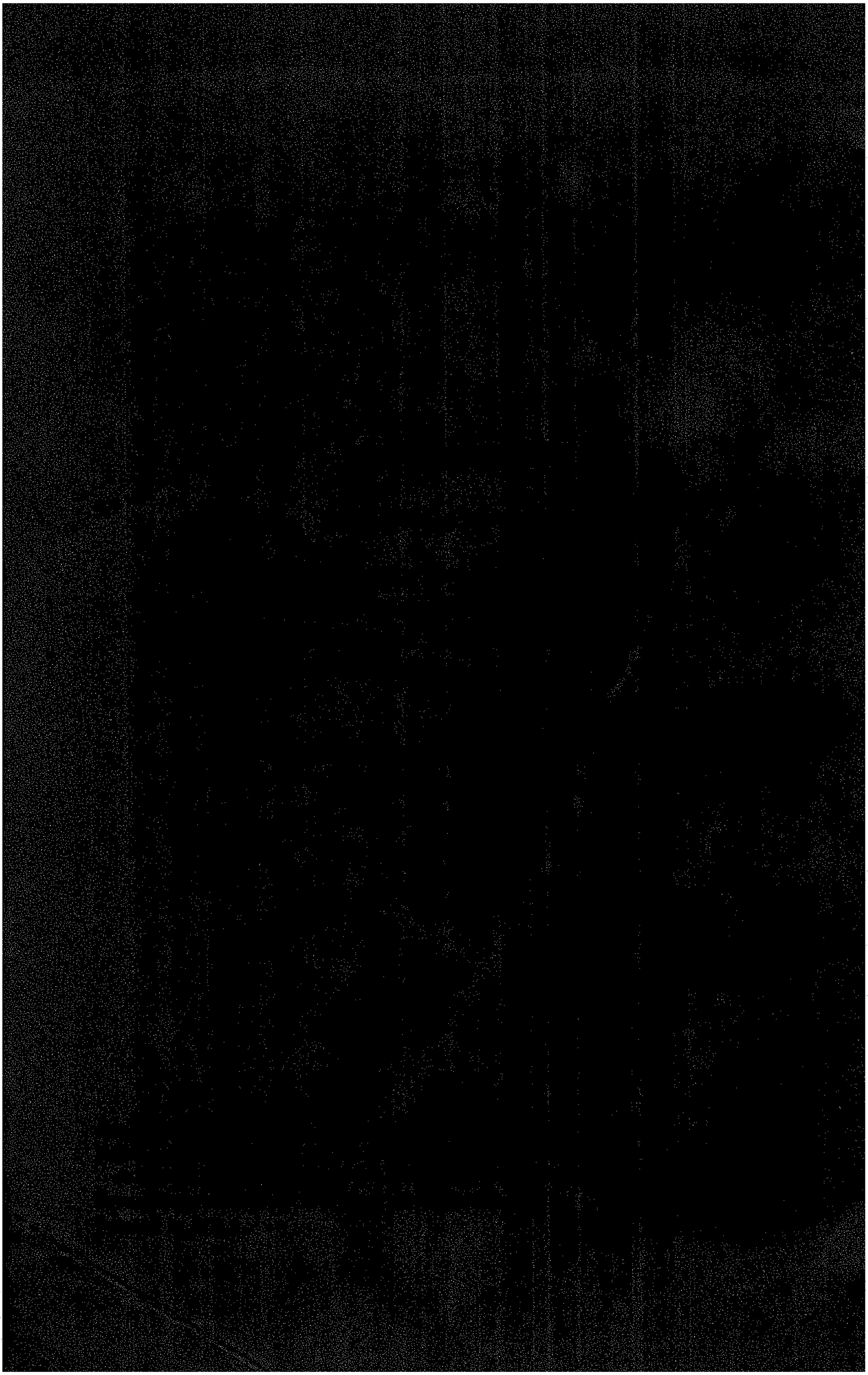
Systems Evaluation Division of the Institute for Defense Analyses, Arlington, Virginia. IDA also announces the appointment of HARRY WILLIAMS and WALTER F. HAHN as Assstant Directors.

GEORGE HAERING of the Operations Evaluation Group, Center for Naval Analyses (CNA) has received the Navy Distinguished Public Service Award. CNA also announces the following appointments: GLOVER S. COLLADAY, ROBERT A. KNISLEY, KENNETH WAYNE WHITT have joined the staff. RALPH E. BEATTY, JR., has been named director of the Warfare Models Divisions of CNA's OEG. The following have also joined CNA's staff: ROBERT W. DOWNEY, ARMAND B. WEISS, ROGER W. WOLLSTADT, ALLAN M. SALZBERG and GLOVER S. COLLADAY.

Operations Research Incorporated (ORI), Silver Spring, Maryland, has announced that the following have joined the staff: JOHN KNIGHT, JOHN S. FONDRK, GEORGE A. MIHRAM, JOHN J. TULLY, STEPHEN D. BENSON, PETER HOCH, CHARLES W. HAMBY, GERALD M. McDONALD, RICHARD A. MAYER. DONALD S. ORKLAND has been elected Vice President of ORI, and FRED ZUSMAN named Director of the corporate Computing Center.

BERNARD OSTLE's book listing in the Fall, 1965, *Bulleting,* was in error, and should have read: OSTLE, B., and R. G. TISCHER, "Statistical Methods in Food Research," Chapter 4 in *Advances in Food Research,* Vol. 5, edited by E. M. MRAK and G. F. STEWART, Academic Press, Inc., New York, 1954.

EUGENE P. VISCO, Research Analysis Committee, will serve on the Lanchester Prize Committee of ORSA for the year 1965–6.



Operations Research Society of America

1966-1967

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OF THE

Operations Research Society of America

Supplement 2 **OPERATIONS RESEARCH** **Volume 14, 1966**

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The Durham, North Carolina, Meeting

REGISTRATION INFORMATION

Registration

The registration desk will be located in the main lobby of the Jack Tar Durham Hotel and will be open:

Sunday, October 16	6:00 PM–10:00 PM
Monday, October 17	8:00 AM– 4:00 PM
Tuesday, October 18	9:00 AM– 4:00 PM
Wednesday, October 19	9:00 AM–Noon

Fees for registration and events are:

Members	$15.00
Non-members	$20.00
Students	$3.00
Banquet	$6.50

An ORSA Meeting Office will be set up at the Jack Tar Durham and will serve as a message center for those attending the meeting.

As is customary, except for a few designated official guests, all attendees are expected to register and pay the registration fee. This includes speakers, panel members, and session chairmen.

Preregistration is strongly encouraged. A preregistration form is enclosed. Please pay only by check or money order (made out to ORSA 30th National Meeting), and mail to DR. MARION R. BRYSON, *ORSA 30th National Meeting, Box EM, Duke Station, Durham, North Carolina 27706.*

Accommodations

The Jack Tar Durham Hotel has reserved a block of rooms for meeting attendees. The daily rates for these rooms are: Single $8.75–10.50; Double $12.75–14.00; Twin $13.50–15.00. A form for hotel reservations is enclosed. The hotel is located in the heart of downtown Durham, and provides free parking for all guests registered at the hotel. The Jack Tar will arrange for any necessary additional rooms with the Holiday Inn located a short distance from the hotel.

There is direct limosine service from the Raleigh-Durham Airport to the Jack Tar Durham Hotel.

LADIES EVENTS

Delegates are encouraged to bring their wives. Tours will be arranged for Duke Gardens, tobacco auctions and cigarette factories in Durham, and the Morehead Planetarium in nearby Chapel Hill. The facilities of several golf courses in the vicinity will also be available. Additional information may be obtained at the registration desk.

COPIES OF PAPERS

Requests for copies of papers should be made directly to the authors. Their addresses are contained in the statement of their affiliation. *Please do not contact any of the committee for the meeting, the session chairmen, or the Editor of the Bulletin about the papers that are presented.*

DESIGNATION OF SESSIONS AND PAPERS

Abbreviations are used to identify the twenty sessions and their papers. The first letter denotes the day of the week, and is **M**, **T**, or **W**. The second letter denotes **AM** or **PM**, and is **A** or **P**. A number from 1 to 4 occurs next, and identifies one of the three or four concurrent sessions. Finally, following a period, the last number identifies the location of a paper within a session. When the entire session is a panel discussion, the period and following number do not appear. For example, **MA4.3** designates the third paper in session 4 on Monday morning.

Invited papers are designated with an asterisk in the program.

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WA3	Alex M. Mood
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WP3	Paul C. Gilmore

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WEDNESDAY PM, OCTOBER 19 UNIVERSITY BALLROOM A

Session WP2: 2:00–5:00 PM

Civil Defense: Contributed Papers

Chairman: ROBERT S. TITCHEN
Research Triangle Institute, Durham, North Carolina

WP2.1 **The Application of Simulation to Civil Defense System Development and Training,** LARRY J. WELLS, *Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.*

WP2.2 **NRDL Target Vulnerability Studies as Applied to the Civil Defense Program,** JUNE BREVDY, *Countermeasures Evaluation Branch, U. S. Naval Radiological Defense Laboratory, San Francisco, California.*

WP2.3 **A System Design for Developing Fallout Shelter in New Construction,** E. L. HILL, *Research Triangle Institute, Durham, North Carolina.*

WP2.4 **An Algorithm for Maximizing Cost Effectiveness of Civil Defense Shelter Development Programs,** P. S. MCMULLAN and STANLEY TRUSTMAN, *Research Triangle Institute, Durham, North Carolina.*

WP2.5 **An Analytical Technique for Urban Casualty Estimation from Multiple Nuclear Weapons,** J. J. HUNTER, *Research Triangle Institute, Durham, North Carolina.*

WEDNESDAY PM, OCTOBER 19 WEDGEWOOD ROOM

Session WP3: 2:00–5:00 PM

Transportation Sciences Section: Invited Papers

Chairman: PAUL C. GILMORE
IBM Corporation, Watson Research Center,
Yorktown Heights, New York.

WP3.1 ***The Analytic Models for Implementing the Economic Impact Studies for the Northeast Corridor Transportation Project,** S. H. PUTMAN, *CONSAD Research Corporation, Pittsburgh, Pennsylvania.*

WP3.2 ***Econometric Study of the Urban Traffic,** JACQUES FEDERWISCH and PIERRE VAN LEEUW, *Société de Recherche Opérationnelle et d'Economie Appliquée, Brussels 5, Belgium.*

WP3.3 ***An Investigation of Aircraft Collision Risks over the North Atlantic,** LEONARD STACHTCHENKO, *Unica Research Company, Montreal, Quebec, Canada.*

WP3.4 ***A Transportation Program for Filling Idle Classrooms in Los Angeles,** T. A. BROWN, *The RAND Corporation, Santa Monica, California.*

Abstracts

MA1.1 *A Systems Approach to Incentive Contracting, HAROLD ASHER, *Office of the Assistant Secretary of Defense, Department of Defense, Washington, D. C. 20301*

Incentive contracting is a widely used method of contracting in the Department of Defense. Its purpose is to motivate the contractor to exceed his target goals in both cost and performance so that both the Department of Defense and he might benefit. The problem of how to structure the incentives is clear in the case of cost; the contractor, provided he meets performance targets, is given a share of any reduction from target development or production cost he can achieve, and a penalty for exceeding the target cost. In the case of performance incentives, the contractor is normally given a premium or a penalty depending on whether he exceeds or fails to meet individually a variety of performance goals, such as speed, range, etc. The problem is that it is normally not determined what it is worth to the DOD to obtain improvements in selected performance characteristics. An approach is suggested which relates contractor premiums and penalties to systems effectiveness and total systems cost which result from the performance characteristics actually achieved.

MA1.2 *A Suggested Treatment of Time-Distributed Expenditures in Defense Systems Analysis, WILLIAM NISKANEN, *Institute for Defense Analyses, Arlington, Virginia.*

A consistent approach is suggested for the following three problems of the use of time-distributed expenditures in defense systems analysis: (a) selection of the planning period, (b) estimation of the "salvage" value of resources at the beginning and end of the planning period, (c) selection of the rate of interest for present value computations. Special attention is focused on the rationale for the use of interest in systems analysis and the choice of the appropriate rate.

MA1.3 *The Treatment of Joint Costs and Joint Goals, ALLAN H. MUIR, *Planning Research Corporation, 1875 Connecticut Avenue NW, Washington, D. C. 20009.*

Much of the value of recent PPB developments is to be found in encouraging cost/effectiveness analysis in the civilian sector of the Federal Government. In mounting support for a given program it is frequently necessary to direct it to more than one objective (e.g., the highway program may serve commercial, defense, or recreational objectives). This has the effect of obscuring the marginal cost and marginal effectiveness intended and of making it difficult to perform cost/effectiveness analyses with respect to the several objectives. The inherently hierarchical structure of DOD has helped to minimize instances in which a given program serves more than one major objective. In civilian programs, such as transportation, the problems of jointness are common and severe. A useful device in obtaining an insight into the purpose of a given optimization analysis is to look at the problem from one level higher in the organizational framework. In the present case this seems to indicate that the costs of activating a program affecting the marginal effectiveness of more than one objective can be effectively studied by separating the analysis, first, into a go-no-go decision and, second, into the accounting allocation of costs to the several objectives required to insure proper effectiveness decisions at the margins. The latter is aided by comparing the cost of program alternatives to the joint cost program under consideration.

MA1.4 *Present Value Criteria in Military Investment, V. BROUSSALIAN, *Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia.*

The rationale for computing the present value of the cost stream of a proposed military investment, often referred to as the problem of discounting costs, is essentially supplied by the wealth maximizing implication of rational individual behavior in the presence of a capital market. It is merely a simple extension of the argument to prescribe the present value of costs as a rational minimand, given the level of anticipated benefits. It is argued in this paper that such an extension is not legitimate when the investment under consideration is of the non-marketable kind, such as military investments. Economic theory does not, in such a situation, imply that the present value of costs—no matter what the discount rate—is a proper measure of the opportunity cost of undertaking the investment. The basic reason for this is shown to be the non-marketability of the benefits which precludes their being used for effecting, even conceptually, any desired change in the net social opportunity cost of the investment via compensatory allocations among individuals and overtime.

MA1.5 *Interest Rate Concepts for Analysis of Government Expenditures, BERNARD SOBIN, *Research Analysis Corporation, McLean, Virginia.*

Much of the current disagreement over what interest rate, if any, should be used in analysis of proposed government expenditures in the Department of Defense, Bureau of Land Reclamation, and other agencies making fairly long-term investments represents disagreements over fundamental questions of: (1) what government administrators are supposed to optimize, (2) the constraints under which they operate, and (3) characteristics of the private economy. There are also, of course, disagreements that arise from ambiguity of definitions and faulty logic. In this paper, a logical framework for analysis is presented and points are identified at which disagreements may reasonably occur. Also noted are some useful propositions about interest rates on which there ought to be wide agreement.

MA2 Problems in the Analysis of Production Systems (Tutorial). Session chaired by GEORGE MURRAY, *School of Engineering, Stanford University, Stanford, California.*

This tutorial session will describe the major decisions required for the operation of a complex industrial production system and will survey the current approaches to their solution. Problems to be discussed will include work force planning, work scheduling, line balancing, replacement, and job sequencing. Limitations to the solution methods now in use will be discussed, and areas of further work will be described. Emphasis will be on the basic nature of the problems, and lectures will be directed to an audience generally unfamiliar with the professional work in the analysis of production systems.

MA3 Mathematical Theories of Combat II: Micro versus Macro Representations (Panel). Session chaired by C. J. ANCKER, JR., *System Development Corporation, Santa Monica, California.*

The panel will discuss the connection between large scale and small scale mathematical models of combat. The focus will be on prediction of the outcome once the engagement has begun. In particular, WEISS will give a brief refresher on Lanchester (Macro) Theory and ANCKER on Stochastic Duel (Micro) Theory. Then WILLIAMS, HELMBOLD, BROOKS, and BROWN will make presentations on various approaches which show the connection between the two. The panel will conclude with a general discussion open to comment from the floor.

MA4.1 A Methodology for Accurately Predicting Demand for Airlift of Military Cargo to Overseas Destinations, WILLIAM E. BILLION and LAWRENCE G. REGAN, *Research Analysis Corporation, McLean, Virginia.*

Recent developments in aircraft technology will create greater airlift capabilities at lower costs. How will this increased capability be effectively utilized by the Department of Defense? Time series extrapolations of air cargo demand have been made in the past for the civil sector of our economy and similar projections have been proposed for military airlift planning. These proved less than successful when compared with actual tonnages generated. This paper will explore a different methodology for predicting airlift demand in the military establishment. Basic data, consisting of approximately 3.8 million commodities and millions of shipments recorded on magnetic automatic data processing tapes, are obtained from all DOD supply management activities. Two information files are established. One is a catalogue file reflecting the physical characteristics (weight, cube, price, etc.) of the commodities which influence total distribution costs of delivering the items to overseas destinations. The second is a demand file containing the actual volume and traffic flow of the commodities. From these files, total distribution costs for air and surface movement are computed by a mathematical model for each commodity to determine the break-even air rate. The economically air eligible commodities are then correlated with the volume and traffic flow to determine the elasticity of demand at various air ton-mile rates. Knowing the operating costs of the new aircraft, logical requirements for airlift can be established. At the same time, criteria for selecting air eligible commodities are based on economic considerations, thus producing the least-cost method of supplying overseas activities.

MA4.2 Analysis of Terminal Air Traffic Flow under Communications Constraints, MATTHEW ROSENSHINE, *State University of New York at Buffalo and Cornell Aeronautical Laboratory.*

Terminal area air traffic queues resulting from communications constraints can be described as queues with Poisson arrivals and service times proportional to the number of aircraft in the queue. The behavior of this type of queueing system is analyzed using the method of imbedded Markov chains. While the analysis shows that there is no equilibrium distribution for such queues and that the expected size of the queue increases without bound with time, the system may be operated at or below a level for which the probability of emptying the queue is high (acceptably close to one). This mode of operation does not require accepting a large penalty in terms of queue size. Further, in the event that the specified operating level of the queueing system should be exceeded, it can be expected to continue to behave "reasonably" at least long enough to insure service to the customers in the queue at the time the operating level was exceeded. The use of actual communications data in the queueing model provides operational levels for queues quite comparable to those actually observed.

MA4.3 Scheduling Empty Box Cars, Abel Bombерault, *IBM Corporation, New York, New York.*

The problem of scheduling empty box cars for a fixed period of time differs from scheduling full cars in that an empty car may go to any point of demand while full cars must go to a specific destination. Because of this difference, the problem of scheduling empty box cars may be formulated as a special network flow problem. We assume as given (1) the train schedule throughout the planning period, (2) the supply of cars at each station as a function of time (negative supply being considered a demand), (3) the cost of going from any station to another on a particular train. The algorithm to find the least cost shipment of cars has the property that the allocation of cars to early trains is computed first. Furthermore, little computer memory is required. Extensions of the algorithm can be made in order to take into account the upgrading of box cars as well as limitations on the lengths of trains

MA4.4 Optimal Resource Allocation in User-Optimized Transportation Networks, Frederick T. Sparrow and Stella Dafermos, *Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland.*

A broad class of transportation networks can be described as "user optimized". Here, travel patterns are set by individual users themselves choosing the cheapest way to arrive at their respective destinations, rather than having their travel patterns dictated by what choice is consistent with some aggregate system optimum, as would be the case in, say, a military transportation problem. A facet of such user optimized transportation network planning models frequently neglected in the literature of operations research is the impact of user optimization on the optimum pattern of resources allocated to improve the network. The paper states the problem of optimal resource allocation in such networks and shows it to be a problem of minimizing a non-linear objective function subject to many linear constraints. An algorithm is presented that takes advantage of a regularity in the objective function, and the computational feasibility of the algorithm for large scale problems is demonstrated by applying the model to a network of realistic size and complexity.

MA4.5 A Transport Improvement Problem Transformable to A Best-Path Problem, A. J. Goldman, *National Bureau of Standards, Washington, D. C.*

Suppose given, for each arc (i,j) of a transport network, both an initial traversal disutility $d(i,j)$ and a function $f(i,j,r)$ describing the reduction in $d(i,j)$ resulting from applying r units of resources to "improve" the arc. For each origin-destination pair, there arises the problem of how a limited resource budget should be allocated among the arcs so as to optimize a best path from origin to destination in the improved network. It is shown here that this problem is transformable to a best-path problem in an enlarged network, if the functions $f(i,j,r)$ are super-additive in r.

MA4.6 A Heuristic Program to Reduce Heating Oil Delivery Costs Incorporating a Regression Technique to Estimate Travel Distances, WARREN H. HAUSMAN, *Cornell University, Ithaca, New York,* and PETER GILMOUR, *Mobil International Oil Corporation, 150 E. 42nd Street, New York, New York.*

Consider a heating oil distributor servicing customers with varying tank capacities, usage rates, and geographical locations. We assume the following operating policy: customers are classified into groups, and when any customer in a group requires a delivery, the entire group is serviced. A heuristic program has been constructed to rearrange customer groupings in an attempt to reduce delivery cost. A key portion of the program involves a least-squares estimate of the travel distance involved in servicing a potential grouping of customers. This estimate is obtained by multiple regression, using the following as independent variables: the number of customers in the group and the standard deviations of the latitudes and longitudes of the customers in the group. The heuristic program considers switching each customer, one at a time, to each of the remaining groups. For each customer, the switch which results in the greatest reduction in cost is made. Then the entire program is repeated a modest number of times for further improvement. Computational results indicate sample cost savings of 18%. The program may also aid in choosing routes for periodic delivery (e.g., dairy or bakery home delivery).

MA4.7 A Queueing System with Multiple Service Time Distributions, CARL M. HARRIS, *Western Electric Company, Inc., Engineering Research Center, Princeton, New Jersey.*

This paper explores a modification of the output discipline for the Poisson input, exponential output, single channel, first-come, first-served queueing system. Instead, the service time distribution of customers beginning service when alone in the system is considered different from that governing service times of all other customers. More specifically, the service times of lone customers are governed by a one parameter gamma distribution, while the service times of all other customers are exponentially distributed. The generating function for the steady state probabilities, $\pi_j = \Pr\{j$ customers in system at an arbitrary point of departure$\}$, of the imbedded chain, $\{X_n \mid X_n =$ number in system after nth customer is serviced$\}$, is obtained, and the steady state probabilities, themselves, are found in closed form. Also, conditions are derived for the existence of these probabilities.

MA4.8 Freeway Traffic Dynamics, C. C. MIESSE and M. A. MARTIN, *The General Electric Company, Missile and Space Division, Valley Forge, Pennsylvania.*

A technique is presented for the analysis of freeway (limited access) traffic, including the effects of mass addition and subtraction as provided by entrances and exits, respectively. A continuum flow solution is obtained by assuming the velocity-density relation provided by safety criteria and utilizing the hydrodynamic flow equation with internal sources or sinks. The continuum flow solution is modified by utilizing discrete sources, and expressing the velocity-density equation as a series of coupled discrete particle equations which are programmed for digital computer solution. Effects of changes in system parameters are readily obtained, and the flow instabilities introduced by (reaction) time-lags are portrayed graphically. A method for the adaptation of the present trunkline and feeders model to multiple-intersection networks is postulated and its application to urban vehicular traffic control is outlined.

MA4.9 Further Stability Considerations for Non-Linear Car Following Models, E. A. UNWIN and L. DUCKSTEIN, *Systems Engineering Department, The University of Arizona, Tucson, Arizona.*

The stability of non-linear car following models is studied by phase-plane techniques and the Liapounov stability theorems. Regions of stability in the phase plane are compared with results obtained by Liapounov's direct method. Various lead-car behaviors are considered, particularly for the reciprocal spacing model. Recent experimental results for time delays and coupling coefficients are incorporated in the study and comparison is made with some previous results. Both closed form and digital computer results are given and some discussion is presented on the relative merits of various appropriate computer techniques.

MA4.10 A Systems View of Traffic Safety: The Evolution of A Problem in Cost-Effectiveness, DAVID M. BOODMAN, *Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts, 02140.*

The recent and rapid growth of public concern with highway safety has created substantial pressure for efforts to improve the safety of the nation's automotive transport system. The systems view, now being taken of this problem, has afforded us a better description of the problem and the alternatives available for its solution. The ultimate usefulness of this approach is still in doubt, despite the fact that no reasonable alternative approach to the management of the safety problem is now available. The evolution of the systems view is traced, and its apparent advantages and remaining drawbacks are discussed with illustrations taken from a recent study of the data-base available for a systems analysis approach to traffic safety management.

MP1.1 *Use of Classical Statistics in Deriving and Evaluating CERs, LT. CHARLES GRAVER, *Office of Assistant Secretary of Defense (Systems Analysis), Department of Defense, Washington, D.C. 20301.*

Statistical Regression theory is frequently being applied in the development of CERs. Hence an understanding of this tool, both its applicability and its limitations, is necessary for developing and reviewing CERs. In this presentation, assumptions and properties of Classical Regression theory are discussed. Interesting statistics are defined and their properties examined. Statistical inference, in the form of prediction intervals, is looked at. Application of the theory to CERs is discussed from the point of view of how well the assumptions are fulfilled. It is concluded that regression techniques can be profitably used, both to make and test the CER, but that such formal statistical statements as prediction intervals are misleading. Though mathematics will be touched upon, the emphasis of the presentation will be directed towards the user.

MP1.2 ***Classical Statistics, Cost Estimating Relationships, and the Facts of Life in Research and Development,** GEORGE LUCHAK, *Princeton University, Princeton, New Jersey.*

The categories of Research & Development are reviewed with an eye to problems of cost estimating as an aid to the trade-offs being made during the Systems Analysis and the Systems Engineering process. The role of classical statistical Cost Estimating Relationships is assessed in contrast with techniques of Project Engineering, Bayesian statistics and the Free Market. Special attention is paid to the institutional, organizational and disciplinary constraints on trade-off decisions.

MP1.3 ***Cost Hypotheses: Their Development and Their Data Implications,** EDWARD H. YATES and BRAD C. FREDERIC, *Defense Research Corporation, 6300 Hollister Avenue, P. O. Box 3587, Santa Barbara, California 93105.*

An important step in the development of a generalized cost estimating equation is the formulation of an initial cost hypothesis—in statistical terms, the selection of a functional form. It is generally agreed that such hypotheses should be consistent with any other physical relationships known to hold for a particular element. But little attention has been given to how this rule might be used in the a priori configuring of functional forms. An examination of several typical cases indicates that there is a general procedure which can be followed. Once articulated, the initial hypothesis essentially defines the type and form of data required to test it. From this standpoint, it is not obvious that the current data systems, either company or DOD initiated, will furnish appropriate information.

MP1.4 ***Use of CERs in the Aerospace Industry,** M. A. MARGOLIS, *The RAND Corporation, 1700 Main Street, Santa Monica, California.*

At the present time two basically different procedures are used to estimate the costs of new, high performance equipments. The older procedure, referred to by some as the "engineering approach," involves the simulation in model shops and by preliminary design groups of all the operations required to develop and produce the new equipment. The second procedure used to estimate new equipment costs begins with an analysis of both the costs and performance capabilities of related equipments, derives the cost-performance or cost-design relationship which would have been most successful in explaining the costs of these related equipments, and then applies this "cost estimating relationship" to the new configuration. The development and use of parametric cost estimating procedure by the Military Services and the planning research organization is not difficult to explain. However, at the present time, a number of major aerospace firms are also actively developing statistical estimating procedures. Their adoption of these devices is not quite so obvious. Have these firms found statistically derived cost estimating relationships a useful adjunct to the "engineering approach"? Or, are the firms responding to such requests as Contract Definition Phase and Pre-contract Definition Phase requirements for cost and performance data on the alternate technical approaches, configurations, and design points studied? This paper reports on an examination of the uses currently being made of parametric estimating procedures by major aerospace firms. As expected, sharp variations were apparent among firms for as both the type of application and the degree. In almost all cases the factors affecting the adoption of cost estimating relationships were found to be unexpectedly involved. In each case an attempt was made to determine both specific applications and their evolution within the firm.

MP1.5 *The Use of CERs in Systems and Force Planning, K. A. CONLEY, *Office of the Comptroller, Headquarters USAF, Washington, D. C., 20030,* and J. D. MCCULLOUGH, *RAND Corporation, 4921 Auburn Avenue, Bethesda, Maryland 20014.*

The Air Force planning environment is briefly described, with emphasis upon Hq USAF activities. The role of cost-effectiveness studies of future weapon and support activities is discussed. The need for cost estimates, and, hence Cost Estimating Relationships (CERs) covering the spectrum of cost elements is shown. For systems in the operational inventory, CERs are used to examine the resource implications of alternative deployments, performance, or activity levels. For future systems, CERs are utilized for all categories of cost, e.g., R&D, Investment, and Annual Operations. The use of ad hoc CERs are often used rather than generalized ones. It is shown that, to some extent, it may always be necessary to have CERs tailored to the problem at hand. For example, one study examined many alternative systems over a 15 year period; gross estimates (and generalized CERs) were appropriate. Another study examined two candidate systems, both available in the near future. Estimates (and CERs) on a very detailed basis were needed to highlight differences. Example CERs for both studies are shown. CER research is underway in all cost areas in the Air Force. AFR 173-2 prescribes the program to generate O&M appropriation data and CERs by program element at the base level. This program is briefly described. While considerable progress has been made in all areas, it should be recognized that there is still room for much improvement.

MP2.1 *Tactical Weaponry and Resource Allocation, S. MOGLEWER, *Douglas Aircraft Company, Long Beach, California.*

The point of view of game theory has been generally ignored by the operations research community to date in studies of resource allocation for tactical weaponry. Since most military resource allocation decisions may be tested in an environment whose outcome is sensitive to decisions of a competitive enemy, the theory provides a logical approach for study of these problems. Utilization of this approach can provide significant insight into the structure of the resource allocation decision and the boundaries of discontinuity for decision surfaces. The existence of these boundaries cannot be determined by a standard mission evaluation cost effectiveness approach or traditional war gaming. They significantly influence the resource allocation decision, particularly where a multiple mission tactical weapon is under consideration. This structure can then be used to constrain and more precisely direct the more detailed cost effectiveness studies. An example of this approach to such diverse problems of resource allocation as fighter and attack aircraft force mix and aircraft carrier force mix will be presented.

MP2.2 *The Strategy of Force Deployment in a Limited War, PAUL D. CHAIKEN, *Naval Warfare Research Center, Stanford Research Institute, Menlo Park, California.*

The strategic basing of limited war forces is analyzed for the near and long-term period. By strategic basing, we mean the deployment of tactical forces throughout the world and the requirements placed upon such a deployment as a function of national objectives pertinent to the many potential theaters-of-operations involved. The study is presented mathematically in a game-theoretic context which attempts to relate the interplay of parameters such as force size, firepower, mobility, logistic response time, overseas basing policies, and geographical constraints, as they might affect the outcome of some future campaign.

MP2.3 *Differential Games in Warfare, RUFUS ISAACS, *Center for Naval Analyses, Arlington, Virginia.*

Game theory being the science of conflict, it might seem undeniable that it be the cardinal tool of military analysis. But its intense capability is still incipient. A primary cause is its difficulty: problems of conflict lie on a higher plateau than those of classical applied mathematics, which can be considered as one-player games. Differential games studies conflicts with an inherent logical structure so that solutions can be obtained analytically. Its military applications embrace game of maneuver with pursuit, evasion firing, maintaining or eluding surveillance, battle games and basic policy questions. The solutions entail a wide variety of phenomena often subtle enough to be imperceptible intuitively. The drawback is that there is no means or organization to sponsor the man-hours of research needed to go from ideas to the complex, varied, and often imprecisely defined problems of contemporary warfare.

MP2.4 *Use of Game Theory in Design of ASW Barriers, FRANCIS SAND, *Mathematica, Inc., Princeton, New Jersey.*

Recent work at MATHEMATICA under contract No. Nonr-4937(00) has considered minmax strategies for patrolling and transiting submarines in a rectangular barrier zone. The transit paths were straight lines but the patroller was given a choice of several patterns. The objective was to secure detection in these games. In the present paper, the emphasis is on the design of an optimal minmax multi-submarine barrier. Within the barrier a number of zones are defined and each submarine is assigned to a zone according to its capabilitites. Transitors are assumed to approach the barrier from a known direction. The games studied will be part of an attempt to formalize the strategic problems of submarine detection.

MP2.5 Problems in The Applications of Game Theory, OSKAR MORGENSTERN, *Princeton University, Princeton, New Jersey.*

(Abstract not available.)

MP3.1 Stability Regimes in the Administration of Criminal Law, Louis G. Vargo, *P. O. Box 68, Escondido, California.* (Sponsored by Alfred Blumstein, *Institute for Defense Analysis, Arlington, Virginia.*)

The dynamics of legal deviation is represented by an extension of the Volterra model of competition between populations. Exogenous changes in the administrative function are admitted to reflect policy decisions on the degree and type of crime prevention, enforcement, prosecution and correction. Other parameters quantify the Malthusian growth (decay) and the encounter-dependent reduction (increase) in the numbers of both the deviant and administrative groups. Stable, that is, bounded, variation with time of these numbers is shown to exist only for certain parametric ranges. In particular, the anarchistic and insurrectional states of the system are identified with two values of the input rate of administrative control. Between these two values stable variations obtain. Cyclical changes are possible only with a *laissez-faire* control policy. Expressions for the average size of each group are obtained so that sensitivity to system parameters are explicitly displayed.

MP3.2 A Method for Locating Warehouses, J. K. Drysdale, *Operations and Market Research, R.C.A. Victor Company Limited, Montreal, Quebec,* and P. J. Sandiford, *Graduate School of Business, McGill University, Montreal, Quebec.*

A fast iterative computer method is described for choosing the near optimal set of warehouses and their locations in a network of $n+1$ potential locations ($n \leqq 54$) of which one is the factory and n are points with known constant demand ($\geqq 0$). The solution for a 35 city distribution network of a manufacturing company was obtained in ten minutes with an IBM 7044. This solution represented a 7% saving over the existing distribution system. The method is based on the shortest route algorithm of Shimbel, combined with an iterative method for adding and removing warehouses. Locating the warehouses and testing the sensitivity to cost parameters is carried on simultaneously. The computer output shows the location of warehouses, identifies the nodes served by each warehouse, gives the optimum product shipping routes and develops the total shipping and warehousing cost. An auxiliary program costs any proposed or existing system for comparison. All programs are in FORTRAN IV. The solution of a second actual case ($n = 55$) is compared with the previous method used by a large Canadian oil company in locating its warehouses.

MP3.3 The Formulation and Solution of the Separation Scheduling Problem, Joseph L. Balintfy and László B. Kovács, *Graduate School of Business Administration, Tulane University, New Orleans, Louisiana.*

Given a restricted assignment problem:

Minimize $\sum c_{ij}x_{ij}$

Subject to $\sum_i x_{ij} \leq b_j$

$$\sum_j x_{ij} = 1$$

$$x_{ij} = 0 \quad \text{or} \quad 1$$

where $x_{ij}=1$ implies that $x_{i-s_j,j} = \cdots = x_{i-1,j} = x_{i+1,j} = \cdots = x_{i+s_j,j} = 0$ and $b_j \geq 1$, $s_j \geq 0$ are given integers, the latter meaning the permitted minimum separation between the entries in the jth column. Assignments with separation scheduling may be required in allocating activities on a discrete time scale where certain number of adjoining time intervals are to be excluded in the optimum solution. This occurs, for instance, in the case of scheduling variety in optimum meal plans. The problem has been solved and an algorithm was programmed by the extension of the branching and bounding technique developed for the traveling salesman problem.

MP3.4 Fluctuations of a Renewal Reward Process, WILLIAM S. JEWELL, *Department of Industrial Engineering and Operations Research, University of California, Berkeley, California.*

Fluctuation theory is concerned with the study of extreme values of sums of independent, arbitrary-valued random values. Simple, but powerful, combinatorial methods due chiefly to E. S. Andersen, F. Spitzer, and W. Feller have recently provided an easy method of attack for what is essentially a one-dimensional random walk. However, operations research models are concerned with fluctuations of reward processes with random underlying "clocks", and reward increments which are correlated with the time since the last payoff; study of these fluctuations is often as important to decision-making, as consideration of the long-term behaviour of the mean reward, or the mean discounted reward. Our extension considers the fluctuations of a cumulative reward process defined over an underlying renewal process, and most of the classical results carry through, including a Weiner-Hopf-type of factorization and certain Waldian results. As applications, we show how certain known relations for the GI/G/1 queue follow directly from a general result for the three-dimensional ladder distribution.

MP3.5 Inventory Control with Random and Regular Replenishment, FRANK C. KAMINSKY, *Industrial Engineering Program, University of Massachusetts, Amherst, Massachusetts.* (Sponsored by SIDNEY SINGER, *International Minerals and Chemicals Corporation, Chicago, Illinois.*)

A constant order quantity model is developed for a basic single commodity storage system. In this system two modes of replenishment, called regular and opportunity replenishment, are assumed to be available. Regular replenishment occurs when the storage facility is emptied. Opportunity replenishment occurs at random points in time and represents a situation in which items for storage can be purchased at a price lower than that of regular replenishment. Both opportunities for replenishment and unit demands are assumed to arise according to a Poisson process. Holding costs and ordering costs, which are assumed to be linear functions of the quantity ordered, are taken to be the relevant costs.

MP3.6 Test Sequence Selection in Diode Manufacture, ALLAN W. HARBAUGH and FRANK F. EICHMAN, JR., *Texas Instruments, Inc., Dallas, Texas.*

Electronic components are typically characterized by sets of electrical and mechanical specifications. Many types of devices have identical mechanical specifications, differing only in electrical properties. From a given production process, many discrete device types can thus be obtained by selection on the basis of electrical characteristics. Specification sets typically intersect, so that relative yields depend on the sequence in which devices are drawn, by electrical test machines, from production lots. Orders for various quantities of different device types must be filled. Limitations in test machine capability typically do not permit simultaneous testing for all devices, so that multiple sequences must be used. This paper presents an application of linear programming to the selection of test sequences and quantities, with multiple lots, in the manufacture of silicon diodes. A mechanized scheme has been developed for generating candidate sequences, which comprehends test machine limitations, and eliminates "bad" sequences by considerations of dominance, using sample data from each lot. The program minimizes the total number of devices necessary to fill a given list of orders. Alternately, rejects may be minimized. A "best" solution is provided when all orders cannot be filled from currently available material.

MP3.7 Selecting and Sequencing Tests in an Adaptive Countdown, RICHARD D. WOLLMER, *The RAND Corporation, Santa Monica, California.* (Sponsored by MURRAY A. GEISLER, *The RAND Corporation, Santa Monica, California.*)

This paper concerns the testing of a space vehicle subsystem just prior to launch. One is given a set of possible tests and an allowable completion time, T. It is desired to select a subset of these tests to perform, and an order in which to perform them, such that the probability the subsystem contains a malfunction at launch time will be minimized subject to the constraint that the sum of the expected completion times of all tests does not exceed T. The effectiveness of a testing sequence depends on the probability that the subsystem contains a malfunction before testing is initiated and on several properties of the individual tests. These properties are: 1) probability the test will detect an existing malfunction, 2) probability the test will indicate falsely the presence of a malfunction, 3) probability the performance of the test will itself introduce a malfunction, and 4) probability the test will discover an introduced malfunction. An interesting consequence of the analysis is that the sequencing problem is independent of the test-selection problem, in the sense that if it is better to perform test i before test j when one particular subset of the tests is chosen for performance, then it is better to perform test i before test j when any subset containing both of them is chosen. This makes it possible to sequence the tests initially and then use dynamic programming to select them.

MP3.8 Operations Research in Regional Solid-Wastes Management: An Example, JOSEPH J. HARRINGTON, *Environmental Health Engineering, Harvard University, Cambridge, Massachusetts.* (Sponsored by MYRON B. FIERING, *Harvard University, Cambridge, Massachusetts.*)

Collection and disposal of municipal solid wastes in the U.S. is a \$4.0 $\times$ 10^9-per-year industry. Only recently has the need for a regional approach to the management of this problem been recognized. This paper reports on the application of operations research techniques to such systems in metropolitan coastal regions:

the specific example is Boston and surrounding communities. An OR approach is especially appropriate because of two proposed innovations: area-wide operation where heretofore the cities and towns separately disposed of their own wastes, usually within their own boundaries, and sea-going incinerators and ocean disposal. The following inter-related mathematical models are discussed: (i) a non-linear, capital-budgeting problem that indicates the optimal (minimum p.v. of costs) investment in incineration and landfill disposal, considering regional development, increases in per capita waste production, and city-planning constraints on land use; and (ii) a large-scale general transportation linear program, including transfer stations, which is heuristically aggregated with the aid of computer-produced map displays.

MP3.9 Considering the Project Planning as a Discrete Multistage Decision Process, RADIVOJ PETROVIĆ, *Institute for Automation and Telecommunications, P. O. Box 906, Belgrade, Yugoslavia.* (Sponsored by GEORGES BRIGHAM, *Arthur Andersen and Company, Seattle, Washington.*)

In this paper the optimization of Project Planning is treated. The technological ordering of jobs in a project is defined by the activity network. The optimization problem involves formulating the predecessor-successor relations of activities in the project as a set of transformations. The scope of work required to complete each job is defined as a state variable. The resources as functions of time allocated to each activity are considered as decision variables. They are constrained when resources are limited. By considering the project planning as a type of multistage decision process with the associated scalar criterion function, the optimization problem is: find values of the decision variables such that the process will move from the initial state in the multidimensional state space to the origin, and that minimize the criterion function. Using the principle of optimality and variational techniques available so far, a new method for selecting the optimal decision is developed. The computational aspects of this method are discussed.

MP3.10 The Structure of the Bacterial Economy, HOWARD M. SHAPIRO, *Department of Surgery, New York University School of Medicine, 550 First Avenue, New York, New York.* (Sponsored by MAX A. WOODBURY, *Duke University Medical Center, Durham, North Carolina.*)

The biochemical reactions involved in the metabolism and growth of a living organism may be considered analogous to the interrelated industries of an economic system. Using this approach, an input-output model of a growing bacterial cell was constructed, in which each chemical component of the cell represented the "product" of a "process" comprising one or more enzymatic reactions. From calculations based on this model, it was possible to calculate the total energy requirement for growth of the cell, and to correctly predict the production of a surplus of each of several cell constituents. The extension of this method to other cellular systems provides a means of studying the energetics of cell division in normal and cancerous cells. It also permits consideration of a fundamental problem in evolutionary theory: Whether a biologically "fit" organism represents an optimal solution to a mathematical programming problem.

MP3.11 The NORMA: A Theory for the Traveling Salesman Problem, NORMAN P. SALZ, *Cornell Aeronautical Laboratory, Inc., Buffalo, New York.*

This paper is a continuation of the approach discussed at the 1965 ORSA Meeting in Boston (Salz, N.P., The NORMA: A Possible Basis For a Theory For The Traveling Salesman Problem, Abstract C4h, Bulletin ORSA, Volume 13 Supplement 1, Spring 1965). The following theorem is proved: *A traveling salesman, or minimum distance route, problem in n points is equivalent to the problem of determining the path of maximum cost through $n-1$ points, where the cost in going from point i to point j is the norma of the deleted point with respect to i, j.* In this context by the cost of a path is meant the total cost starting at any point and going to a different point in the set and passing through each remaining point once and only once. In particular for $(123 \cdots n)$ to be the minimum distance route it is necessary and sufficient that the sum of the normas of point 1 with respect to 2, 3 and 3, 4 and $\cdots$, and $n-1$, n be the path of maximum cost through the points 2, 3, $\cdots$, n. The theorem readily reduces to an algorithm and applications are presented.

TA1 The Concept of Threat (Panel). Session chaired by MARTIN SHUBIK, *Yale University, New Haven, Connecticut.*

The purpose of this panel is to examine some of the different concepts of threat as they are used in various disciplines, such as war gaming, diplomacy, game theory, social psychology, and so forth. There has been a considerable lack of clarity in defining the relationship between the idea of a threat as an absolute commitment to a line of action, and a threat as a move in a verbal or symbolic game. This has led to a great amount of misinterpretation in what can be learned from 2 × 2 matrix games either as experimental devices or paradigms for international affairs.

TA2.1 *Simulation of a Radio-Dispatched Truck Fleet, JOHN W. SAWYER, *Department of Mathematics, Wake Forest College, Winston-Salem, North Carolina, and Consulting Mathematician, R. J. Reynolds Tobacco Company, Winston-Salem, North Carolina.*

There are two purposes in mind in presenting this paper. First, it gives the anatomy of an operations research project from its original formulation until its completion. Second, it gives a detailed look at the mechanics of a practical and successful simulation. The R. J. Reynolds Tobacco Company operates a fleet of trucks which are used to haul materials and workmen to engineering construction projects, and to haul materials from factory to factory within a 20-mile radius. A request for a truck is relayed to a radio dispatcher and, if a truck is available, it is dispatched by means of a radio message. In many cases a crew of workmen is to be transported. If no truck is available, the lost time of this crew places a financial penalty on the non-availability of a truck. In general, no penalty accrues if materials only are to be hauled. This simulation of the truck fleet arose from the simple question, "How many trucks should we be operating?" A thorough analysis of past and present operating data was made, thus obtaining various operational patterns and frequency distributions which could be duplicated in the simulation.

Crew wait time was determined by the simulation as a function of the number of trucks in operation and the average number of requests per day for trucks. Balancing truck costs against crew wait costs, it was possible to give an operating curve which gives the optimum number of trucks to operate for minimum cost, for varying levels of requests for trucks.

TA2.2 *A Computer Simulation Model of the Textile Industry, THOMAS H. NAYLOR, WILLIAM H. WALLACE, and EARL SASSER, *Department of Economics, Duke University, Durham, North Carolina.*

This paper contains a description of a preliminary version of an econometric model of the textile industry. The purpose of the model is to conduct computer simulation experiments both for forecasting the behavior of the textile industry and testing the effects of various state and federal governmental policies on the textile industry. Among the endogenous variables included in the model are wages, employment, output, profit, and investment. The model is recursive and consists of a set of linear stochastic equations whose parameters were estimated by econometric estimation methods. The parameters of the model were estimated from monthly data for the time period 1950 through 1965. In conducting computer simulation experiments with the model the simulation language developed by Charles Holt and others at the University of Wisconsin called PROGRAM SIMULATE was used.

TA2.3 *The Use of Operations Research in Improving Product Mix, R. W. LINDSAY, *American Enka Corporation, Enka, North Carolina.*

This paper is slanted toward the commercial, marketing, and profitability aspects of product mix studies more so than the mathematical and technical aspects. The desirability of building sales limitations into the matrix of restrictions is discussed, along with methods of developing the necessary data. Practical use of the results of Optimum Product Mix studies in improving profitability is explored. The effect of multiple plant sites, the availability of alternate production processes, and variable pricing policies are also covered. The importance of using the proper level of costs in calculating the profit function to be maximized is explained. The use of the Simplex Method of Linear Programming is briefly explained.

TA3 Effectiveness Measures for Cost-Effectiveness Studies (Panel). Session chaired by DAVID E. VAN TIJN, *Research Analysis Corporation, McLean, Virginia.*

A panel discussion of the degree of generality that seems to prevail within effectiveness concepts and the extent to which different measures of effectiveness can be transferred from one system to another.

TA3.1 *System Effectiveness in Urban Poverty Programs, JOHN KETELLE, *Ketelle Associates, 1770 Lancaster Pike, Paoli, Pennsylavnia.*

Community Action Programs are currently the largest single component of the anti-poverty effort, accounting for over 40% of the federal expenditures under the Economic Opportunity Act. This paper reports the first stage of a study of the

WEDNESDAY PM, OCTOBER 19 University Ballroom A

Session WP2: 2:00–5:00 PM

Civil Defense: Contributed Papers

Chairman: Robert S. Titchen
Research Triangle Institute, Durham, North Carolina

WP2.1 **The Application of Simulation to Civil Defense System Development and Training,** Larry J. Wells, *Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.*

WP2.2 **NRDL Target Vulnerability Studies as Applied to the Civil Defense Program,** June Brevdy, *Countermeasures Evaluation Branch, U. S. Naval Radiological Defense Laboratory, San Francisco, California.*

WP2.3 **A System Design for Developing Fallout Shelter in New Construction,** E. L. Hill, *Research Triangle Institute, Durham, North Carolina.*

WP2.4 **An Algorithm for Maximizing Cost Effectiveness of Civil Defense Shelter Development Programs,** P. S. McMullan and Stanley Trustman, *Research Triangle Institute, Durham, North Carolina.*

WP2.5 **An Analytical Technique for Urban Casualty Estimation from Multiple Nuclear Weapons,** J. J. Hunter, *Research Triangle Institute, Durham, North Carolina.*

WEDNESDAY PM, OCTOBER 19 Wedgewood Room

Session WP3: 2:00–5:00 PM

Transportation Sciences Section: Invited Papers

Chairman: Paul C. Gilmore
IBM Corporation, Watson Research Center,
Yorktown Heights, New York.

WP3.1 ***The Analytic Models for Implementing the Economic Impact Studies for the Northeast Corridor Transportation Project,** S. H. Putman, *CONSAD Research Corporation, Pittsburgh, Pennsylvania.*

WP3.2 ***Econometric Study of the Urban Traffic,** Jacques Federwisch and Pierre Van Leeuw, *Société de Recherche Opérationnelle et d'Economie Appliquée, Brussels 5, Belgium.*

WP3.3 ***An Investigation of Aircraft Collision Risks over the North Atlantic,** Leonard Stachtchenko, *Unica Research Company, Montreal, Quebec, Canada.*

WP3.4 ***A Transportation Program for Filling Idle Classrooms in Los Angeles,** T. A. Brown, *The RAND Corporation, Santa Monica, California.*

Abstracts

MA1.1 *A Systems Approach to Incentive Contracting, HAROLD ASHER, *Office of the Assistant Secretary of Defense, Department of Defense, Washington, D. C. 20301*

Incentive contracting is a widely used method of contracting in the Department of Defense. Its purpose is to motivate the contractor to exceed his target goals in both cost and performance so that both the Department of Defense and he might benefit. The problem of how to structure the incentives is clear in the case of cost; the contractor, provided he meets performance targets, is given a share of any reduction from target development or production cost he can achieve, and a penalty for exceeding the target cost. In the case of performance incentives, the contractor is normally given a premium or a penalty depending on whether he exceeds or fails to meet individually a variety of performance goals, such as speed, range, etc. The problem is that it is normally not determined what it is worth to the DOD to obtain improvements in selected performance characteristics. An approach is suggested which relates contractor premiums and penalties to systems effectiveness and total systems cost which result from the performance characteristics actually achieved.

MA1.2 *A Suggested Treatment of Time-Distributed Expenditures in Defense Systems Analysis, WILLIAM NISKANEN, *Institute for Defense Analyses, Arlington, Virginia.*

A consistent approach is suggested for the following three problems of the use of time-distributed expenditures in defense systems analysis: (a) selection of the planning period, (b) estimation of the "salvage" value of resources at the beginning and end of the planning period, (c) selection of the rate of interest for present value computations. Special attention is focused on the rationale for the use of interest in systems analysis and the choice of the appropriate rate.

MA1.3 *The Treatment of Joint Costs and Joint Goals, ALLAN H. MUIR, *Planning Research Corporation, 1875 Connecticut Avenue NW, Washington, D. C. 20009.*

Much of the value of recent PPB developments is to be found in encouraging cost/effectiveness analysis in the civilian sector of the Federal Government. In mounting support for a given program it is frequently necessary to direct it to more than one objective (e.g., the highway program may serve commercial, defense, or recreational objectives). This has the effect of obscuring the marginal cost and marginal effectiveness intended and of making it difficult to perform cost/effectiveness analyses with respect to the several objectives. The inherently hierarchical structure of DOD has helped to minimize instances in which a given program serves more than one major objective. In civilian programs, such as transportation, the problems of jointness are common and severe. A useful device in obtaining an insight into the purpose of a given optimization analysis is to look at the problem from one level higher in the organizational framework. In the present case this seems to indicate that the costs of activating a program affecting the marginal effectiveness of more than one objective can be effectively studied by separating the analysis, first, into a go-no-go decision and, second, into the accounting allocation of costs to the several objectives required to insure proper effectiveness decisions at the margins. The latter is aided by comparing the cost of program alternatives to the joint cost program under consideration.

MA1.4 *Present Value Criteria in Military Investment, V. BROUSSALIAN, *Center for Naval Analyses, 1401 Wilson Boulevard, Arlington, Virginia.*

The rationale for computing the present value of the cost stream of a proposed military investment, often referred to as the problem of discounting costs, is essentially supplied by the wealth maximizing implication of rational individual behavior in the presence of a capital market. It is merely a simple extension of the argument to prescribe the present value of costs as a rational minimand, given the level of anticipated benefits. It is argued in this paper that such an extension is not legitimate when the investment under consideration is of the non-marketable kind, such as military investments. Economic theory does not, in such a situation, imply that the present value of costs—no matter what the discount rate—is a proper measure of the opportunity cost of undertaking the investment. The basic reason for this is shown to be the non-marketability of the benefits which precludes their being used for effecting, even conceptually, any desired change in the net social opportunity cost of the investment via compensatory allocations among individuals and overtime.

MA1.5 *Interest Rate Concepts for Analysis of Government Expenditures, BERNARD SOBIN, *Research Analysis Corporation, McLean, Virginia.*

Much of the current disagreement over what interest rate, if any, should be used in analysis of proposed government expenditures in the Department of Defense, Bureau of Land Reclamation, and other agencies making fairly long-term investments represents disagreements over fundamental questions of: (1) what government administrators are supposed to optimize, (2) the constraints under which they operate, and (3) characteristics of the private economy. There are also, of course, disagreements that arise from ambiguity of definitions and faulty logic. In this paper, a logical framework for analysis is presented and points are identified at which disagreements may reasonably occur. Also noted are some useful propositions about interest rates on which there ought to be wide agreement.

MA2 Problems in the Analysis of Production Systems (Tutorial). Session chaired by GEORGE MURRAY, *School of Engineering, Stanford University, Stanford, California.*

This tutorial session will describe the major decisions required for the operation of a complex industrial production system and will survey the current approaches to their solution. Problems to be discussed will include work force planning, work scheduling, line balancing, replacement, and job sequencing. Limitations to the solution methods now in use will be discussed, and areas of further work will be described. Emphasis will be on the basic nature of the problems, and lectures will be directed to an audience generally unfamiliar with the professional work in the analysis of production systems.

MA3 Mathematical Theories of Combat II: Micro versus Macro Representations (Panel). Session chaired by C. J. ANCKER, JR., *System Development Corporation, Santa Monica, California.*

The panel will discuss the connection between large scale and small scale mathematical models of combat. The focus will be on prediction of the outcome once the engagement has begun. In particular, WEISS will give a brief refresher on Lanchester (Macro) Theory and ANCKER on Stochastic Duel (Micro) Theory. Then WILLIAMS, HELMBOLD, BROOKS, and BROWN will make presentations on various approaches which show the connection between the two. The panel will conclude with a general discussion open to comment from the floor.

MA4.1 A Methodology for Accurately Predicting Demand for Airlift of Military Cargo to Overseas Destinations, WILLIAM E. BILLION and LAWRENCE G. REGAN, *Research Analysis Corporation, McLean, Virginia.*

Recent developments in aircraft technology will create greater airlift capabilities at lower costs. How will this increased capability be effectively utilized by the Department of Defense? Time series extrapolations of air cargo demand have been made in the past for the civil sector of our economy and similar projections have been proposed for military airlift planning. These proved less than successful when compared with actual tonnages generated. This paper will explore a different methodology for predicting airlift demand in the military establishment. Basic data, consisting of approximately 3.8 million commodities and millions of shipments recorded on magnetic automatic data processing tapes, are obtained from all DOD supply management activities. Two information files are established. One is a catalogue file reflecting the physical characteristics (weight, cube, price, etc.) of the commodities which influence total distribution costs of delivering the items to overseas destinations. The second is a demand file containing the actual volume and traffic flow of the commodities. From these files, total distribution costs for air and surface movement are computed by a mathematical model for each commodity to determine the break-even air rate. The economically air eligible commodities are then correlated with the volume and traffic flow to determine the elasticity of demand at various air ton-mile rates. Knowing the operating costs of the new aircraft, logical requirements for airlift can be established. At the same time, criteria for selecting air eligible commodities are based on economic considerations, thus producing the least-cost method of supplying overseas activities.

MA4.2 Analysis of Terminal Air Traffic Flow under Communications Constraints, MATTHEW ROSENSHINE, *State University of New York at Buffalo and Cornell Aeronautical Laboratory.*

Terminal area air traffic queues resulting from communications constraints can be described as queues with Poisson arrivals and service times proportional to the number of aircraft in the queue. The behavior of this type of queueing system is analyzed using the method of imbedded Markov chains. While the analysis shows that there is no equilibrium distribution for such queues and that the expected size of the queue increases without bound with time, the system may be operated at or below a level for which the probability of emptying the queue is high (acceptably close to one). This mode of operation does not require accepting a large penalty in terms of queue size. Further, in the event that the specified operating level of the queueing system should be exceeded, it can be expected to continue to behave "reasonably" at least long enough to insure service to the customers in the queue at the time the operating level was exceeded. The use of actual communications data in the queueing model provides operational levels for queues quite comparable to those actually observed.

MA4.3 Scheduling Empty Box Cars, ABEL BOMBERAULT, *IBM Corporation, New York, New York.*

The problem of scheduling empty box cars for a fixed period of time differs from scheduling full cars in that an empty car may go to any point of demand while full cars must go to a specific destination. Because of this difference, the problem of scheduling empty box cars may be formulated as a special network flow problem. We assume as given (1) the train schedule throughout the planning period, (2) the supply of cars at each station as a function of time (negative supply being considered a demand), (3) the cost of going from any station to another on a particular train. The algorithm to find the least cost shipment of cars has the property that the allocation of cars to early trains is computed first. Furthermore, little computer memory is required. Extensions of the algorithm can be made in order to take into account the upgrading of box cars as well as limitations on the lengths of trains.

MA4.4 Optimal Resource Allocation in User-Optimized Transportation Networks, FREDERICK T. SPARROW and STELLA DAFERMOS, *Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland.*

A broad class of transportation networks can be described as "user optimized". Here, travel patterns are set by individual users themselves choosing the cheapest way to arrive at their respective destinations, rather than having their travel patterns dictated by what choice is consistent with some aggregate system optimum, as would be the case in, say, a military transportation problem. A facet of such user optimized transportation network planning models frequently neglected in the literature of operations research is the impact of user optimization on the optimum pattern of resources allocated to improve the network. The paper states the problem of optimal resource allocation in such networks and shows it to be a problem of minimizing a non-linear objective function subject to many linear constraints. An algorithm is presented that takes advantage of a regularity in the objective function, and the computational feasibility of the algorithm for large scale problems is demonstrated by applying the model to a network of realistic size and complexity.

MA4.5 A Transport Improvement Problem Transformable to A Best-Path Problem, A. J. GOLDMAN, *National Bureau of Standards, Washington, D. C.*

Suppose given, for each arc (i,j) of a transport network, both an initial traversal disutility $d(i,j)$ and a function $f(i,j,r)$ describing the reduction in $d(i,j)$ resulting from applying r units of resources to "improve" the arc. For each origin-destination pair, there arises the problem of how a limited resource budget should be allocated among the arcs so as to optimize a best path from origin to destination in the improved network. It is shown here that this problem is transformable to a best-path problem in an enlarged network, if the functions $f(i,j,r)$ are super-additive in r.

MA4.6 A Heuristic Program to Reduce Heating Oil Delivery Costs Incorporating a Regression Technique to Estimate Travel Distances,

WARREN H. HAUSMAN, *Cornell University, Ithaca, New York*, and PETER GILMOUR, *Mobil International Oil Corporation, 150 E. 42nd Street, New York, New York.*

Consider a heating oil distributor servicing customers with varying tank capacities, usage rates, and geographical locations. We assume the following operating policy: customers are classified into groups, and when any customer in a group requires a delivery, the entire group is serviced. A heuristic program has been constructed to rearrange customer groupings in an attempt to reduce delivery cost. A key portion of the program involves a least-squares estimate of the travel distance involved in servicing a potential grouping of customers. This estimate is obtained by multiple regression, using the following as independent variables: the number of customers in the group and the standard deviations of the latitudes and longitudes of the customers in the group. The heuristic program considers switching each customer, one at a time, to each of the remaining groups. For each customer, the switch which results in the greatest reduction in cost is made. Then the entire program is repeated a modest number of times for further improvement. Computational results indicate sample cost savings of 18%. The program may also aid in choosing routes for periodic delivery (e.g., dairy or bakery home delivery).

MA4.7 A Queueing System with Multiple Service Time Distributions,

CARL M. HARRIS, *Western Electric Company, Inc., Engineering Research Center, Princeton, New Jersey.*

This paper explores a modification of the output discipline for the Poisson input, exponential output, single channel, first-come, first-served queueing system. Instead, the service time distribution of customers beginning service when alone in the system is considered different from that governing service times of all other customers. More specifically, the service times of lone customers are governed by a one parameter gamma distribution, while the service times of all other customers are exponentially distributed. The generating function for the steady state probabilities, $\pi_j = \Pr\{j$ customers in system at an arbitrary point of departure$\}$, of the imbedded chain, $\{X_n \mid X_n =$ number in system after nth customer is serviced$\}$, is obtained, and the steady state probabilities, themselves, are found in closed form. Also, conditions are derived for the existence of these probabilities.

MA4.8 Freeway Traffic Dynamics,

C. C. MIESSE and M. A. MARTIN, *The General Electric Company, Missile and Space Division, Valley Forge, Pennsylvania.*

A technique is presented for the analysis of freeway (limited access) traffic, including the effects of mass addition and subtraction as provided by entrances and exits, respectively. A continuum flow solution is obtained by assuming the velocity-density relation provided by safety criteria and utilizing the hydrodynamic flow equation with internal sources or sinks. The continuum flow solution is modified by utilizing discrete sources, and expressing the velocity-density equation as a series of coupled discrete particle equations which are programmed for digital computer solution. Effects of changes in system parameters are readily obtained, and the flow instabilities introduced by (reaction) time-lags are portrayed graphically. A method for the adaptation of the present trunkline and feeders model to multiple-intersection networks is postulated and its application to urban vehicular traffic control is outlined.

MA4.9 Further Stability Considerations for Non-Linear Car Following Models, E. A. Unwin and L. Duckstein, *Systems Engineering Department, The University of Arizona, Tucson, Arizona.*

The stability of non-linear car following models is studied by phase-plane techniques and the Liapounov stability theorems. Regions of stability in the phase plane are compared with results obtained by Liapounov's direct method. Various lead-car behaviors are considered, particularly for the reciprocal spacing model. Recent experimental results for time delays and coupling coefficients are incorporated in the study and comparison is made with some previous results. Both closed form and digital computer results are given and some discussion is presented on the relative merits of various appropriate computer techniques.

MA4.10 A Systems View of Traffic Safety: The Evolution of A Problem in Cost-Effectiveness, David M. Boodman, *Arthur D. Little, Inc., Acorn Park, Cambridge, Massachusetts, 02140.*

The recent and rapid growth of public concern with highway safety has created substantial pressure for efforts to improve the safety of the nation's automotive transport system. The systems view, now being taken of this problem, has afforded us a better description of the problem and the alternatives available for its solution. The ultimate usefulness of this approach is still in doubt, despite the fact that no reasonable alternative approach to the management of the safety problem is now available. The evolution of the systems view is traced, and its apparent advantages and remaining drawbacks are discussed with illustrations taken from a recent study of the data-base available for a systems analysis approach to traffic safety management.

MP1.1 *Use of Classical Statistics in Deriving and Evaluating CERs, Lt. Charles Graver, *Office of Assistant Secretary of Defense (Systems Analysis), Department of Defense, Washington, D.C. 20301.*

Statistical Regression theory is frequently being applied in the development of CERs. Hence an understanding of this tool, both its applicability and its limitations, is necessary for developing and reviewing CERs. In this presentation, assumptions and properties of Classical Regression theory are discussed. Interesting statistics are defined and their properties examined. Statistical inference, in the form of prediction intervals, is looked at. Application of the theory to CERs is discussed from the point of view of how well the assumptions are fulfilled. It is concluded that regression techniques can be profitably used, both to make and test the CER, but that such formal statistical statements as prediction intervals are misleading. Though mathematics will be touched upon, the emphasis of the presentation will be directed towards the user.

MP1.2 *Classical Statistics, Cost Estimating Relationships, and the Facts of Life in Research and Development, GEORGE LUCHAK, *Princeton University, Princeton, New Jersey.*

The categories of Research & Development are reviewed with an eye to problems of cost estimating as an aid to the trade-offs being made during the Systems Analysis and the Systems Engineering process. The role of classical statistical Cost Estimating Relationships is assessed in contrast with techniques of Project Engineering, Bayesian statistics and the Free Market. Special attention is paid to the institutional, organizational and disciplinary constraints on trade-off decisions.

MP1.3 *Cost Hypotheses: Their Development and Their Data Implications, EDWARD H. YATES and BRAD C. FREDERIC, *Defense Research Corporation, 5300 Hollister Avenue, P. O. Box 3587, Santa Barbara, California 93105.*

An important step in the development of a generalized cost estimating equation is the formulation of an initial cost hypothesis—in statistical terms, the selection of a functional form. It is generally agreed that such hypotheses should be consistent with any other physical relationships known to hold for a particular element. But little attention has been given to how this rule might be used in the a priori configuring of functional forms. An examination of several typical cases indicates that there is a general procedure which can be followed. Once articulated, the initial hypothesis essentially defines the type and form of data required to test it. From this standpoint, it is not obvious that the current data systems, either company or DOD initiated, will furnish appropriate information.

MP1.4 *Use of CERs in the Aerospace Industry, M. A. MARGOLIS, *The RAND Corporation, 1700 Main Street, Santa Monica, California.*

At the present time two basically different procedures are used to estimate the costs of new, high performance equipments. The older procedure, referred to by some as the "engineering approach," involves the simulation in model shops and by preliminary design groups of all the operations required to develop and produce the new equipment. The second procedure used to estimate new equipment costs begins with an analysis of both the costs and performance capabilities of related equipments, derives the cost-performance or cost-design relationship which would have been most successful in explaining the costs of these related equipments, and then applies this "cost estimating relationship" to the new configuration. The development and use of parametric cost estimating procedure by the Military Services and the planning research organization is not difficult to explain. However, at the present time, a number of major aerospace firms are also actively developing statistical estimating procedures. Their adoption of these devices is not quite so obvious. Have these firms found statistically derived cost estimating relationships a useful adjunct to the "engineering approach"? Or, are the firms responding to such requests as Contract Definition Phase and Pre-contract Definition Phase requirements for cost and performance data on the alternate technical approaches, configurations, and design points studied? This paper reports on an examination of the uses currently being made of parametric estimating procedures by major aerospace firms. As expected, sharp variations were apparent among firms for as both the type of application and the degree. In almost all cases the factors affecting the adoption of cost estimating relationships were found to be unexpectedly involved. In each case an attempt was made to determine both specific applications and their evolution within the firm.

MP1.5 *The Use of CERs in Systems and Force Planning, K. A. CONLEY, *Office of the Comptroller, Headquarters USAF, Washington, D. C., 20030,* and J. D. MCCULLOUGH, *RAND Corporation, 4921 Auburn Avenue, Bethesda, Maryland 20014.*

The Air Force planning environment is briefly described, with emphasis upon Hq USAF activities. The role of cost-effectiveness studies of future weapon and support activities is discussed. The need for cost estimates, and, hence Cost Estimating Relationships (CERs) covering the spectrum of cost elements is shown. For systems in the operational inventory, CERs are used to examine the resource implications of alternative deployments, performance, or activity levels. For future systems, CERs are utilized for all categories of cost, e.g., R&D, Investment, and Annual Operations. The use of ad hoc CERs are often used rather than generalized ones. It is shown that, to some extent, it may always be necessary to have CERs tailored to the problem at hand. For example, one study examined many alternative systems over a 15 year period; gross estimates (and generalized CERs) were appropriate. Another study examined two candidate systems, both available in the near future. Estimates (and CERs) on a very detailed basis were needed to highlight differences. Example CERs for both studies are shown. CER research is underway in all cost areas in the Air Force. AFR 173-2 prescribes the program to generate O&M appropriation data and CERs by program element at the base level. This program is briefly described. While considerable progress has been made in all areas, it should be recognized that there is still room for much improvement.

MP2.1 *Tactical Weaponry and Resource Allocation, S. MOGLEWER, *Douglas Aircraft Company, Long Beach, California.*

The point of view of game theory has been generally ignored by the operations research community to date in studies of resource allocation for tactical weaponry. Since most military resource allocation decisions may be tested in an environment whose outcome is sensitive to decisions of a competitive enemy, the theory provides a logical approach for study of these problems. Utilization of this approach can provide significant insight into the structure of the resource allocation decision and the boundaries of discontinuity for decision surfaces. The existence of these boundaries cannot be determined by a standard mission evaluation cost effectiveness approach or traditional war gaming. They significantly influence the resource allocation decision, particularly where a multiple mission tactical weapon is under consideration. This structure can then be used to constrain and more precisely direct the more detailed cost effectiveness studies. An example of this approach to such diverse problems of resource allocation as fighter and attack aircraft force mix and aircraft carrier force mix will be presented.

MP2.2 *The Strategy of Force Deployment in a Limited War, PAUL D. CHAIKEN, *Naval Warfare Research Center, Stanford Research Institute, Menlo Park, California.*

The strategic basing of limited war forces is analyzed for the near and long-term period. By strategic basing, we mean the deployment of tactical forces throughout the world and the requirements placed upon such a deployment as a function of national objectives pertinent to the many potential theaters-of-operations involved. The study is presented mathematically in a game-theoretic context which attempts to relate the interplay of parameters such as force size, firepower, mobility, logistic response time, overseas basing policies, and geographical constraints, as they might affect the outcome of some future campaign.

MP2.3 *Differential Games in Warfare, RUFUS ISAACS, *Center for Naval Analyses, Arlington, Virginia.*

Game theory being the science of conflict, it might seem undeniable that it be the cardinal tool of military analysis. But its intense capability is still incipient. A primary cause is its difficulty: problems of conflict lie on a higher plateau than those of classical applied mathematics, which can be considered as one-player games. Differential games studies conflicts with an inherent logical structure so that solutions can be obtained analytically. Its military applications embrace game of maneuver with pursuit, evasion firing, maintaining or eluding surveillance, battle games and basic policy questions. The solutions entail a wide variety of phenomena often subtle enough to be imperceptible intuitively. The drawback is that there is no means or organization to sponsor the man-hours of research needed to go from ideas to the complex, varied, and often imprecisely defined problems of contemporary warfare.

MP2.4 *Use of Game Theory in Design of ASW Barriers, FRANCIS SAND, *Mathematica, Inc., Princeton, New Jersey.*

Recent work at MATHEMATICA under contract No. Nonr-4937(00) has considered minmax strategies for patrolling and transiting submarines in a rectangular barrier zone. The transit paths were straight lines but the patroller was given a choice of several patterns. The objective was to secure detection in these games. In the present paper, the emphasis is on the design of an optimal minmax multi-submarine barrier. Within the barrier a number of zones are defined and each submarine is assigned to a zone according to its capabilitites. Transitors are assumed to approach the barrier from a known direction. The games studied will be part of an attempt to formalize the strategic problems of submarine detection.

MP2.5 Problems in The Applications of Game Theory, OSKAR MORGENSTERN, *Princeton University, Princeton, New Jersey.*

(Abstract not available.)

MP3.1 Stability Regimes in the Administration of Criminal Law, Louis G. Vargo, *P. O. Box 68, Escondido, California.* (Sponsored by Alfred Blumstein, *Institute for Defense Analysis, Arlington, Virginia.*)

The dynamics of legal deviation is represented by an extension of the Volterra model of competition between populations. Exogenous changes in the administrative function are admitted to reflect policy decisions on the degree and type of crime prevention, enforcement, prosecution and correction. Other parameters quantify the Malthusian growth (decay) and the encounter-dependent reduction (increase) in the numbers of both the deviant and administrative groups. Stable, that is, bounded, variation with time of these numbers is shown to exist only for certain parametric ranges. In particular, the anarchistic and insurrectional states of the system are identified with two values of the input rate of administrative control. Between these two values stable variations obtain. Cyclical changes are possible only with a *laissez-faire* control policy. Expressions for the average size of each group are obtained so that sensitivity to system parameters are explicitly displayed.

MP3.2 A Method for Locating Warehouses, J. K. Drysdale, *Operations and Market Research, R.C.A. Victor Company Limited, Montreal, Quebec,* and F. J. Sandiford, *Graduate School of Business, McGill University, Montreal, Quebec.*

A fast iterative computer method is described for choosing the near optimal set of warehouses and their locations in a network of $n+1$ potential locations ($n \leqq 54$) of which one is the factory and n are points with known constant demand ($\geqq 0$). The solution for a 35 city distribution network of a manufacturing company was obtained in ten minutes with an IBM 7044. This solution represented a 7% saving over the existing distribution system. The method is based on the shortest route algorithm of Shimbel, combined with an iterative method for adding and removing warehouses. Locating the warehouses and testing the sensitivity to cost parameters is carried on simultaneously. The computer output shows the location of warehouses, identifies the nodes served by each warehouse, gives the optimum product shipping routes and develops the total shipping and warehousing cost. An auxiliary program costs any proposed or existing system for comparison. All programs are in FORTRAN IV. The solution of a second actual case ($n=55$) is compared with the previous method used by a large Canadian oil company in locating its warehouses.

MP3.3 The Formulation and Solution of the Separation Scheduling Problem, Joseph L. Balintfy and László B. Kovács, *Graduate School of Business Administration, Tulane University, New Orleans, Louisiana.*

Given a restricted assignment problem:

Minimize $\sum c_{ij}x_{ij}$

Subject to $\sum_i x_{ij} \leq b_j$

$$\sum_j x_{ij} = 1$$

$$x_{ij} = 0 \quad \text{or} \quad 1$$

where $x_{ij}=1$ implies that $x_{i-s_j,j} = \cdots = x_{i-1,j} = x_{i+1,j} = \cdots = x_{i+s_j,j} = 0$ and $b_j \geq 1$, $s_j \geq 0$ are given integers, the latter meaning the permitted minimum separation between the entries in the jth column. Assignments with separation scheduling may be required in allocating activities on a discrete time scale where certain number of adjoining time intervals are to be excluded in the optimum solution. This occurs, for instance, in the case of scheduling variety in optimum meal plans. The problem has been solved and an algorithm was programmed by the extension of the branching and bounding technique developed for the traveling salesman problem.

MP3.4 Fluctuations of a Renewal Reward Process, WILLIAM S. JEWELL, *Department of Industrial Engineering and Operations Research, University of California, Berkeley, California.*

Fluctuation theory is concerned with the study of extreme values of sums of independent, arbitrary-valued random values. Simple, but powerful, combinatorial methods due chiefly to E. S. Andersen, F. Spitzer, and W. Feller have recently provided an easy method of attack for what is essentially a one-dimensional random walk. However, operations research models are concerned with fluctuations of reward processes with random underlying "clocks", and reward increments which are correlated with the time since the last payoff; study of these fluctuations is often as important to decision-making, as consideration of the long-term behaviour of the mean reward, or the mean discounted reward. Our extension considers the fluctuations of a cumulative reward process defined over an underlying renewal process, and most of the classical results carry through, including a Weiner-Hopf-type of factorization and certain Waldian results. As applications, we show how certain known relations for the GI/G/1 queue follow directly from a general result for the three-dimensional ladder distribution.

MP3.5 Inventory Control with Random and Regular Replenishment, FRANK C. KAMINSKY, *Industrial Engineering Program, University of Massachusetts, Amherst, Massachusetts.* (Sponsored by SIDNEY SINGER, *International Minerals and Chemicals Corporation, Chicago, Illinois.*)

A constant order quantity model is developed for a basic single commodity storage system. In this system two modes of replenishment, called regular and opportunity replenishment, are assumed to be available. Regular replenishment occurs when the storage facility is emptied. Opportunity replenishment occurs at random points in time and represents a situation in which items for storage can be purchased at a price lower than that of regular replenishment. Both opportunities for replenishment and unit demands are assumed to arise according to a Poisson process. Holding costs and ordering costs, which are assumed to be linear functions of the quantity ordered, are taken to be the relevant costs.

MP3.6 Test Sequence Selection in Diode Manufacture, ALLAN W. HARBAUGH and FRANK F. EICHMAN, JR., *Texas Instruments, Inc., Dallas, Texas.*

Electronic components are typically characterized by sets of electrical and mechanical specifications. Many types of devices have identical mechanical specifications, differing only in electrical properties. From a given production process, many discrete device types can thus be obtained by selection on the basis of electrical characteristics. Specification sets typically intersect, so that relative yields depend on the sequence in which devices are drawn, by electrical test machines, from production lots. Orders for various quantities of different device types must be filled. Limitations in test machine capability typically do not permit simultaneous testing for all devices, so that multiple sequences must be used. This paper presents an application of linear programming to the selection of test sequences and quantities, with multiple lots, in the manufacture of silicon diodes. A mechanized scheme has been developed for generating candidate sequences, which comprehends test machine limitations, and eliminates "bad" sequences by considerations of dominance, using sample data from each lot. The program minimizes the total number of devices necessary to fill a given list of orders. Alternately, rejects may be minimized. A "best" solution is provided when all orders cannot be filled from currently available material.

MP3.7 Selecting and Sequencing Tests in an Adaptive Countdown, Richard D. Wollmer, *The RAND Corporation, Santa Monica, California.* (Sponsored by Murray A. Geisler, *The RAND Corporation, Santa Monica, California.*)

This paper concerns the testing of a space vehicle subsystem just prior to launch. One is given a set of possible tests and an allowable completion time, T. It is desired to select a subset of these tests to perform, and an order in which to perform them, such that the probability the subsystem contains a malfunction at launch time will be minimized subject to the constraint that the sum of the expected completion times of all tests does not exceed T. The effectiveness of a testing sequence depends on the probability that the subsystem contains a malfunction before testing is initiated and on several properties of the individual tests. These properties are: 1) probability the test will detect an existing malfunction, 2) probability the test will indicate falsely the presence of a malfunction, 3) probability the performance of the test will itself introduce a malfunction, and 4) probability the test will discover an introduced malfunction. An interesting consequence of the analysis is that the sequencing problem is independent of the test-selection problem, in the sense that if it is better to perform test i before test j when one particular subset of the tests is chosen for performance, then it is better to perform test i before test j when any subset containing both of them is chosen. This makes it possible to sequence the tests initially and then use dynamic programming to select them.

MP3.8 Operations Research in Regional Solid-Wastes Management: An Example, Joseph J. Harrington, *Environmental Health Engineering, Harvard University, Cambridge, Massachusetts.* (Sponsored by Myron B. Fiering, *Harvard University, Cambridge, Massachusetts.*)

Collection and disposal of municipal solid wastes in the U.S. is a \$4.0 $\times$ 10^9-per-year industry. Only recently has the need for a regional approach to the management of this problem been recognized. This paper reports on the application of operations research techniques to such systems in metropolitan coastal regions:

the specific example is Boston and surrounding communities. An OR approach is especially appropriate because of two proposed innovations: area-wide operation where heretofore the cities and towns separately disposed of their own wastes, usually within their own boundaries, and sea-going incinerators and ocean disposal. The following inter-related mathematical models are discussed: (i) a non-linear, capital-budgeting problem that indicates the optimal (minimum p.v. of-costs) investment in incineration and landfill disposal, considering regional development, increases in per capita waste production, and city-planning constraints on land use; and (ii) a large-scale general transportation linear program, including transfer stations, which is heuristically aggregated with the aid of computer-produced map displays.

MP3.9 Considering the Project Planning as a Discrete Multistage Decision Process, RADIVOJ PETROVIĆ, *Institute for Automation and Telecommunications, P. O. Box 906, Belgrade, Yugoslavia.* (Sponsored by GEORGES BRIGHAM, *Arthur Andersen and Company, Seattle, Washington.*)

In this paper the optimization of Project Planning is treated. The technological ordering of jobs in a project is defined by the activity network. The optimization problem involves formulating the predecessor-successor relations of activities in the project as a set of transformations. The scope of work required to complete each job is defined as a state variable. The resources as functions of time allocated to each activity are considered as decision variables. They are constrained when resources are limited. By considering the project planning as a type of multistage decision process with the associated scalar criterion function, the optimization problem is: find values of the decision variables such that the process will move from the initial state in the multidimensional state space to the origin, and that minimize the criterion function. Using the principle of optimality and variational techniques available so far, a new method for selecting the optimal decision is developed. The computational aspects of this method are discussed.

MP3.10 The Structure of the Bacterial Economy, HOWARD M. SHAPIRO, *Department of Surgery, New York University School of Medicine, 550 First Avenue, New York, New York.* (Sponsored by MAX A. WOODBURY, *Duke University Medical Center, Durham, North Carolina.*)

The biochemical reactions involved in the metabolism and growth of a living organism may be considered analogous to the interrelated industries of an economic system. Using this approach, an input-output model of a growing bacterial cell was constructed, in which each chemical component of the cell represented the "product" of a "process" comprising one or more enzymatic reactions. From calculations based on this model, it was possible to calculate the total energy requirement for growth of the cell, and to correctly predict the production of a surplus of each of several cell constituents. The extension of this method to other cellular systems provides a means of studying the energetics of cell division in normal and cancerous cells. It also permits consideration of a fundamental problem in evolutionary theory: Whether a biologically "fit" organism represents an optimal solution to a mathematical programming problem.

MP3.11 The NORMA: A Theory for the Traveling Salesman Problem, NORMAN P. SALZ, *Cornell Aeronautical Laboratory, Inc , Buffalo, New York.*

This paper is a continuation of the approach discussed at the 1965 ORSA Meeting in Boston (Salz, N.P., The NORMA: A Possible Basis For a Theory For The Traveling Salesman Problem, Abstract C4h, Bulletin ORSA, Volume 13 Supplement 1, Spring 1965). The following theorem is proved: *A traveling salesman, or minimum distance route, problem in n points is equivalent to the problem of determining the path of maximum cost through $n-1$ points, where the cost in going from point i to point j is the norma of the deleted point with respect to i, j.* In this context by the cost of a path is meant the total cost starting at any point and going to a different point in the set and passing through each remaining point once and only once. In particular for $(123 \cdots n)$ to be the minimum distance route it is necessary and sufficient that the sum of the normas of point 1 with respect to 2, 3 and 3, 4 and $\cdots$, and $n-1$, n be the path of maximum cost through the points 2, 3, $\cdots$, n. The theorem readily reduces to an algorithm and applications are presented.

TA1 The Concept of Threat (Panel). Session chaired by MARTIN SHUBIK, *Yale University, New Haven, Connecticut.*

The purpose of this panel is to examine some of the different concepts of threat as they are used in various disciplines, such as war gaming, diplomacy, game theory, social psychology, and so forth. There has been a considerable lack of clarity in defining the relationship between the idea of a threat as an absolute commitment to a line of action, and a threat as a move in a verbal or symbolic game. This has led to a great amount of misinterpretation in what can be learned from 2 × 2 matrix games either as experimental devices or paradigms for international affairs.

TA2.1 *Simulation of a Radio-Dispatched Truck Fleet, JOHN W. SAWYER, *Department of Mathematics, Wake Forest College, Winston-Salem, North Carolina, and Consulting Mathematician, R. J. Reynolds Tobacco Company, Winston-Salem, North Carolina.*

There are two purposes in mind in presenting this paper. First, it gives the anatomy of an operations research project from its original formulation until its completion. Second, it gives a detailed look at the mechanics of a practical and successful simulation. The R. J. Reynolds Tobacco Company operates a fleet of trucks which are used to haul materials and workmen to engineering construction projects, and to haul materials from factory to factory within a 20-mile radius. A request for a truck is relayed to a radio dispatcher and, if a truck is available, it is dispatched by means of a radio message. In many cases a crew of workmen is to be transported. If no truck is available, the lost time of this crew places a financial penalty on the non-availability of a truck. In general, no penalty accrues if materials only are to be hauled. This simulation of the truck fleet arose from the simple question, "How many trucks should we be operating?" A thorough analysis of past and present operating data was made, thus obtaining various operational patterns and frequency distributions which could be duplicated in the simulation.

Crew wait time was determined by the simulation as a function of the number of trucks in operation and the average number of requests per day for trucks. Balancing truck costs against crew wait costs, it was possible to give an operating curve which gives the optimum number of trucks to operate for minimum cost, for varying levels of requests for trucks.

TA2.2 *A Computer Simulation Model of the Textile Industry, THOMAS H. NAYLOR, WILLIAM H. WALLACE, and EARL SASSER, *Department of Economics, Duke University, Durham, North Carolina.*

This paper contains a description of a preliminary version of an econometric model of the textile industry. The purpose of the model is to conduct computer simulation experiments both for forecasting the behavior of the textile industry and testing the effects of various state and federal governmental policies on the textile industry. Among the endogenous variables included in the model are wages, employment, output, profit, and investment. The model is recursive and consists of a set of linear stochastic equations whose parameters were estimated by econometric estimation methods. The parameters of the model were estimated from monthly data for the time period 1950 through 1965. In conducting computer simulation experiments with the model the simulation language developed by Charles Holt and others at the University of Wisconsin called PROGRAM SIMULATE was used.

TA2.3 *The Use of Operations Research in Improving Product Mix, R. W. LINDSAY, *American Enka Corporation, Enka, North Carolina.*

This paper is slanted toward the commercial, marketing, and profitability aspects of product mix studies more so than the mathematical and technical aspects. The desirability of building sales limitations into the matrix of restrictions is discussed, along with methods of developing the necessary data. Practical use of the results of Optimum Product Mix studies in improving profitability is explored. The effect of multiple plant sites, the availability of alternate production processes, and variable pricing policies are also covered. The importance of using the proper level of costs in calculating the profit function to be maximized is explained. The use of the Simplex Method of Linear Programming is briefly explained.

TA3 Effectiveness Measures for Cost-Effectiveness Studies (Panel). Session chaired by DAVID E. VAN TIJN, *Research Analysis Corporation, McLean, Virginia.*

A panel discussion of the degree of generality that seems to prevail within effectiveness concepts and the extent to which different measures of effectiveness can be transferred from one system to another.

TA3.1 *System Effectiveness in Urban Poverty Programs, JOHN KETELLE, *Ketelle Associates, 1770 Lancaster Pike, Paoli, Pennsylavnia.*

Community Action Programs are currently the largest single component of the anti-poverty effort, accounting for over 40% of the federal expenditures under the Economic Opportunity Act. This paper reports the first stage of a study of the effectiveness of this program in one large city. It outlines pertinent ways in which the target population is being measured. It investigates appropriate descriptions of the program components. It discusses techniques by which the effect of the programs on the community may be measured or anticipated. Furthermore, it looks for ways in which the program influences and is influenced by existing and local organizations and efforts.

TA3.2 *Measures of Effectiveness for the Field Army Medical Support System, JOANN LANGSTON, *Operations Research, Inc., Silver Spring, Maryland.*

The traditional measures of the effectiveness of the Army Medical Service are mortality, morbidity, and return-to-duty rates. These rates are convenient for a broad or historical measurement of effectiveness; they are, nevertheless, relatively insensitive to changes in specific medical factors such as facilities, numbers and skill levels in theater, evacuation methods, or holding policies. More sensitive measures which are used for the models include availability and utilization of personnel, utilization of facilities, and reduction of patient delays. The patients, personnel and logistical elements can then be subjected to tradeoffs of performance, cost and delay.

TA3.3 *Generalized Effectiveness Methodology, S. SELTZER, *Computer Applications, Inc., 525 Madison Avenue, New York, New York,* and P. GIORDANO, *U. S. Naval Applied Science Laboratory.*

This paper considers a Generalized Effectiveness Methodology developed to provide a Program Manager with the means of systematically choosing between alternate system configurations, proposed to meet a particular mission requirement, which are subject to constraints (time to deployment, weight, power, etc.) and resource limitations (cost, manpower, supplies). Systems effectiveness measures are developed in terms of specific hardware characteristics, system performance characteristics, and support system characteristics and are shown to be directly related to the amount of acceptable degradation of performance measures such as probability of detection.

TA3.4 *System Effectiveness Definition and Measurements, DON COSTELLO, *ARINC Research Corporation, Riva Road, Annapolis, Maryland.*

With the theory developed in the WESIAC report as a point of departure, the more general problem of systems effectiveness will be discussed, such as: (a) How does one prove existence of a measure, (b) How does one measure or compute the required quantities. In this context the kind of systems to which the WESIAC approach applies will be characterized, and the possibility of parallel developments for more complex systems will be explored.

TA4.1 Stochastic Duels with Round-to-Round Correlation, DAVID R. FINLEY, *Cornell Aeronautic Laboratory, Falls Church, Virginia.* (Sponsored by FLOYD I. HILL, *Cornell Aeronautic Laboratory, Falls Church, Virginia.*)

The fundamental stochastic duel as defined by Williams and Ancker is modified by assuming that the probability of a hit resulting in a kill is less than one, and that hit probabilities depend on the results of previous shots. It is shown that under very general conditions positive correlation always works to a contestant's disadvantage, while negative correlation always works to his advantage. Of particular interest is the case where shots for one or both participants, classified as hit or miss, are Markov dependent Bernoulli trials. It is shown that for any distribution of time between shots, a single firer may be characterized by a series of independent repeated cycles. By use of this structure, the duel is solved up to the inversion of a characteristic function. It is also shown that for low order Erlang firing times, the solution can be more easily obtained by algebraic methods. Numerical results obtained by these methods are exhibited.

TA4.2 Study of the Analytic Rationale and Methodology for Determining the Composition of the USAF "Mission Support Fleet," WILLIAM GRODOWITZ, *Headquarters USAF, Directorate of Aerospace Programs, DCS/P&R, Washington, D. C.*

USAF mission support aircraft are those auxiliary aircraft assigned to Major Air Force Commands in order to support proficiency training (for pilots currently not cockpit-assigned), for peacetime transportation purposes and for special mission and emergency wartime uses. Primary mission or force structure operational aircraft are either not procured in sufficient numbers to accomplish these tasks or are not designed for these purposes. For the past several years procurement or modernization of the mission support fleet (currently totaling about 1500 aircraft for USAF) has been denied, partially because a "rationale" acceptable to OSD has not been evolved. Such rationale would permit both determination of "the requirement" for mission support aircraft—as dictated by its four interrelated job aspects, i.e., pilot proficiency, etc.,—and its fulfillment, in terms responsive to cost and effectiveness assessment. The study shows alternative approaches which were assessed for satisfaction of the workload aspects associated with mission support aircraft requirements. It also gives the methodology which was developed (i.e., a fleet selector model) for the purpose of deriving a preferred mission support aircraft fleet. The Study served as the basis of USAF program force changes, proposed for the mission support fleet, which were approved by OSD.

TA4.3 A General Simulation of an Information Transfer System for the Analysis of the Operational Effectiveness of Military Communication Networks, JAMES F. DAUGHTRY, III, *Computer Applications, Inc., San Diego, California.* (Sponsored by C. J. ANCKER, JR., *System Development Corporation, Santa Monica, California.*)

This paper presents a general simulation model of an information transfer system for the analysis of the operational effectiveness of military communication networks. The information transfer system considered is composed of nodes and branches between these nodes, and the functional capability of processing classes of information sets from node to node. The simulation is based upon a time status record accounting for the time of the events and actions upon information sets in discrete intervals for short periods of time. The nodes can be representative of persons, relay stations, ships, planes, satellites, etc. The branches are representative of the physical media between two nodes and take into account such factors as enemy interference (jamming) and physical conditions that affect the transmission of information. The information sets are defined by length and an initial time for processing the information from some node in the system, and by a routing vector which maps the nodes through which the information must be processed. The measure of system effectiveness utilized is the sum of the amount of time an information set spends in queue, waiting for a failed branch to be cleared, plus the time spent waiting for a failed station at a node to resume operation. From these data one can determine the average delay and dispersion of delays for a traffic sample of information. Also for each node in the network the model can be used to determine the number of information sets in the queue and the expected time to clear the queue every time an information set arrives at a node from which the average queue length and the average waiting time are computed. The model proper is presented in a set of diagrams: (a) Diagram I: Fundamental Diagram For Simulating An Information Transfer System, (b) Diagram II: Entering Information Set, q, on Node M_k, Priority Table, (c) Diagram III: Transmitter Process, (d) Diagram IV: Branch Process, (e) Diagram V: Receiver Process, and (f) Diagram VI: Priority Assignment Routine. Finally, typical U. S. Navy operational deployment is presented, its communications network is constructed, and the analysis of its structure is developed, indicating where system branches are essential to the accomplishment of a given mission.

TA4.4 Research on Cost-Estimating Relationships for O&M,A, JOHN G. PHILLIPS, *Research Analysis Corporation, McLean, Virginia.*

The research reported in this paper develops a methodology for determining the cost impact of the operation and maintenance, Army (O&M,A) appropriation for the analysis of proposed force changes. The methodology is built around the Army's financial accounting system and relies primarily on Army budget data. Each account is classified to a level of activity detail that can be matched with quantities, either physical or measured in dollars, and for which there are descriptions of what specific O&M,A costs the account includes. Classification of O&M,A activities as to type of force dependency enables the computation of coefficients that relate specific activity costs to physical measures. A complete set of O&M,A cost estimating relationships (CERs), except for costs of training military occupational specialities, illustrates how CERs can developed from the Army's financial accounting system.

TA4.5 An Application of Reliability Analysis to a Problem of Communications, LEONARD B. WEINGARTEN, *Research Analysis Corporation, McLean, Virginia.*

The study described in this paper had as one of its goals the establishing of a optimal command-control communications system to support a special mission. To this end (and to satisfy certain other requirements of mission optimizing) a field test was run for about three months by the US Army. The required data was gathered and subsequently analyzed with an eye to intelligibility, link reliability, mode of transmission, and radio selection. The CCC analysis methodology included techniques most usually found in reliability analyses. The purpose of this paper is to show one example of techniques common to one field being used in another.

TA4.6 A Model of the Submarine Commander's Decision Processes for Evaluation of Susceptibility to Tactical Deception,

James R. Apel, *Advanced Weapons Systems, North American Aviation, Inc., Columbus, Ohio,* and Albert B. Bishop, *Department of Industrial Engineering, Ohio State University, Columbus, Ohio.*

A current problem in the analysis of the effectiveness of fleet operations is the evaluation of tactical deception doctrine and equipment employed against enemy submarines. The utility of tactical deception devices is directly related to the susceptibility of the submarine commander to be deceived and the sensitivity of the effectiveness of his operations to the deception. A model of the submarine commander's decision processes is developed which includes all phases of an encounter from initial receipt of a signal to weapons launch and evasion. This model, which is both probabilistic and dynamic, interrelates prior information available to the commander with current sensor inputs, crew and ship status, and the commander's estimates of the results of the various decisions open to him at each point in time. Sufficient flexibility is provided to allow varying degrees of emphasis on either the normative or descriptive aspects of the decision-making process and to be applicable in a large number of situations. The model is illustrated for an encounter involving a single nuclear submarine and a carrier task force to indicate areas of greatest potential value of tactical deception devices.

TA4.7 Military Applications of Industrial Dynamics,

Joseph Krol, *School of Industrial Engineering, Georgia Institute of Technology, Atlanta, Georgia.* (Sponsored by Robert N. Lehrer, *Georgia Institute of Technology, Atlanta, Georgia.*)

Industrial dynamics, developed by Professor J. W. Forrester of M.I.T., is a digital simulation technique combined with the philosophy of industrial systems. Its applications are not limited to industrial problems but may be used in the simulation of dynamic phenomena in other areas such as economics, sociology, biology, transportation, and military science. Industrial dynamics models may be quite extensive and may contain as many as 2,000 variables. In order to observe time-dependent relationships in so many variables, a special-purpose compiler called DYNAMO was designed for use with the IBM 7094 computer. The desired variables are printed out and graphical plots generated. Four military applications of industrial dynamics, identified as Model I, Model II, Model III, and Model IV are discussed in this paper. Model I simulates the behavior of an army platoon exposed to enemy fire. The model consists of some 75 variables. Model II simulates the behavior of a mechanized division in an assault river crossing. Model III simulates the behavior of a military transportation system necessary to adequately support a selected combat force in a particular theater of operations. Model IV simulates the behavior of an insurgent force developing in a South-East Asian community through the enemy infiltration.

TP1.1 *Operations Research on Police Problems in the United Kingdom, A. G. McDonald, *Scientific Adviser's Branch, Home Office, London, England.*

A review of projects undertaken by the OR group in the Home Office will be presented. Some of them are: assessment of patrol and intelligence operations; development of methods of crime detection; examination of information flow; equipment evaluation; resource allocation.

TP1.2 *Scheduling of the Patrol Force in Alexandria, Virginia, F. R. Frola, R. E. Gordon, and S. S. Richmond, *North American Aviation, Inc., 1735 I Street, N. W., Washington, D. C.*

This paper is a report on a joint project involving the City of Alexandria, Virginia, and North American Aviation, Inc., to investigate the utilization of the police patrol forces. Specifically, the objective of the study is to generate a profile of the time-demand for police services and to schedule the available patrol force to meet this demand. Detailed operational data was collected over a 6-month period and subjected to statistical analysis, including (1) Pearson curve fitting to obtain the service-time distribution of police calls, (2) analysis of variance to estimate daily and seasonal fluctuations, and (3) measures of the time spent by patrolmen in various activities. An experiment is being designed to estimate the effects of preventive patrol on crime. Such knowledge will enable the optimum allocation of the time available for preventive patrol. In particular, this information will complete the demand-for-service profile and thereby permit the scheduling part of the problem to be accomplished. A non-linear integer programming representation of the scheduling problem can be used to achieve the scheduling, once the above relationships involving preventable crime are ascertained. As an interim step a graphical approximation of the solution has been obtained by estimating the class of preventable crimes and by ignoring the effects of patrol on these crimes.

TP1.3 *The Design of an Emergency Road Service System with Implications for the Deployment of Police Forces, Michael Leyzorek, *25 N. Washington Street, Port Washington, New York.*

There is an analogy between problems of operating an emergency road service system and those of deploying effectively a police force. In both cases service demands from the public arise randomly. However, there is a probability distribution describing the likelihood that a given number of service demands will occur at a given time and place. The problem is to match numbers and locations of service personnel and vehicles to numbers and locations of service demands and to provide a desired standard of performance. A city is often classified into geographic areas, each of which becomes the responsibility of an element of the service force; consequently the available force is frequently idle because of the random demand pattern. This paper describes an alternative approach in which a completely mobile force controlled from a central station supplies the service requirements by shifting the available force from area to area in accordance with the changing demand pattern as previously analyzed, thus obtaining far better utilization of available service resources and providing any desired standard of performance. In designing a police system it is essential to apply a suitable priority to various services to insure that correct allocation has been made of police resources.

TP1.4 *A Model of Social Conflict, HERBERT K. WEISS, *Litton Data Systems Division, 8000 Woodley Avenue, Van Nuys, California.*

Crime data indicates a generally higher per capita crime rate in large cities than in small cities. A Maxwellian model of criminal activity is hypothesized, leading to the conjecture that per capita crime rate (other factors being equal) will be proportional to population density. The model is next modified to include the deterrent effect of police operations. A comparison with reported crime rates for individual cities is presented, and some projections are made of the effect of increased urbanization and the changing age distribution of the population on growth in the crime rate. Flow diagrams are presented for the interaction between the crime prevention and law enforcement process and the crime rate. The principal parameters are further developed in terms of measurable characteristics of the conflict process. The effect of scale of organization is discussed. Some general conclusions are developed regarding measures of effectiveness and cost-effectiveness trades.

TP2.1 Fighter Analysis—Tactical Air Combat (FANTAC), CHARLES B. WHALEY, *Los Angeles Division, North American Aviation, Inc., International Airport, Los Angeles, California.* (Sponsored by WENDELL J. THOMPSON, *North American Aviation, Los Angeles, California.*)

The recent emphasis on air-to-air combat has resulted in the development of a digital computer simulation model called FANTAC to simulate a three dimensional, one-on-one-fighter-fighter duel. This development effort was sponsored by the Directorate of Studies and Analysis, Headquarters USAF (formerly known as the Air Battle Analysis Center). FANTAC models the detection, tactics, and kill portions of the duel. In the detection area the capability exists to simulate the performance of radar, infrared, and visual sensor systems. In the kill area guns, radar and infrared guided missiles, and unguided rockets can be simulated. The tactics area is composed of three parts, viz. (1) a "decision tree" to select a maneuver (hard turn, yo-yo, etc.) based upon the situation existing at the moment. (2) a series of subroutines to compute the changes in an aircraft's control variables (roll rate, pitch rate, and thrust) to effect the desired maneuvers, and (3) six degree-of-freedom aerodynamic equations of motion to calculate the trajectories of the duelists. All maneuvers occur in three dimensions. FANTAC contains two distinct logic loops in that each aircraft reacts to the position and capabilities of the other. FANTAC may be used to evaluate sensor system capabilities, aircraft performance capabilities, weapon capabilities, and tactics.

TP2.2 An Optimum Missile Test Program Based on Cost-Effectiveness, J. SMILLIE and F. WERTHEIMER, *Vitro Laboratories, Division of Vitro Corporation of America, 200 Pleasant Valley Way, West Orange, New Jersey.* (Sponsored by FRANCIS JOSEPH FELIX, *Vitro Laboratories*).

This paper describes a methodology, based on cost-effectiveness concepts, with which to establish policy guidelines for attaining an optimum missile test program. The methodology includes consideration of a) a missile inventory of varying missile ages and missile capabilities; b) a military requirement to keep a fixed price level on ready alert; c) an on-going practice of cyclic inspection and repair; d) an on-going program of missile testing. The methodology centers about the formulation of a risk function, expressed in terms of the four considerations listed above and their associated cost. The variations of this function are examined, and its sensitivity to the number of missiles tested is determined. Previous efforts in this field have been mainly concerned with the evolution of an optimum test policy when only random failures appear. The present paper considers the entry of failure modes as the result of missile ageing. The problem of detecting the entry of such a mode is discussed, because the optimum test policy is strongly dependent upon such detection, and the time after entry when failure mode detection occurs. The paper also deals with the possibility of multiple failure modes. Using the risk function, the methodology provides decision criteria on a cost-effectiveness basis for an optimum test policy, for the repair/replace policy, and for a missile procurement policy.

TP2.3 A Cost-Effective Method to Determine Ground Survivability of Strategic Aircraft, Samuel C. Colwell, *The Boeing Company, Commercial Airplane Division, Renton, Washington.*

This paper is concerned with determining a strategy which will allow an effective retaliatory force of strategic aircraft to survive an enemy surprise attack on the United States. The ways to ensure this survival include aircraft dispersal, hardening, level of alert and combinations of these variables. The study develops the analysis which will determine a ground survivability policy based on the above variables and which minimizes the cost of purchasing, operating and maintaining the aircraft while ensuring a set survivability level. The model allows the user to perform a parametric analysis to determine a cost-effective allocation of the number of bases, the number of aircraft per base, the degree of hardening, etc., and takes into account such factors as warning time, reaction time, level of attack and aiming errors.

TP2.4 A Procedure for Aiding Strategic Aircraft Route Planning, Saul I. Gass, John R. Norton, and David B. Webster, *IBM Federal Systems Division, Federal Systems Center, Bethesda, Maryland.*

The problem of determining recommended target approach paths for certain strategic aircraft was approached as that of finding a shortest route through a network. That is, an aircraft is assumed to approach a target by flying over a sequence of grid points. Associated with each grid point is a numerical value proportional to the risk involved in flying across it, the risk being a function of its coverage by defensive weapons. A sequence of points leading to the target and return constitutes a possible route, and the risk involved in flying this route is assumed to be proportional to the sum of the risks associated with each point on the route. Since the problem involved a large number of nodes, it was highly important from a computational point of view regarding computer running time that an acyclic network be developed which would also contain all reasonable flight paths. This permitted the set of nodes to be processed once and the shortest (minimum risk) route determined by a single pass through by the computer.

TP2.5 Altitude Flight Gains and Losses, H. A. Ralles, *Dept. 3621, Zone 35, Northrop Norair, 3901 West Broadway, Hawthorne, California.*

The threat of antiaircraft fire to low-flying aircraft decreases markedly as the aircraft flies closer to the terrain, but the price of this margin of safety is a correspondingly increased risk of flying into the ground. A model is presented to evaluate the two risks as a function of aircraft speed and altitude above the terrain mean for varying degrees of terrain roughness. Since terrain roughness can be characterized statistically, the probabilities of terrain prominences can be used to evaluate line-of-sight probability, and probability of aircraft impact with the terrain. The utility of the model is shown by an illustrative example.

TP2.6 A Pattern of Military Analysis for a Computerized Fixed Increment War Game, F. J. Murray, W. E. Sewell, and K. A. Heimes, *Special Research in Numerical Analysis, Duke University, Durham, North Carolina.* (Sponsored by George E. Nicholson, Jr., *University of North Carolina, Chapel Hill, North Carolina.*)

The simulation of a military operation which is normally part of war gaming is obtained by a procedure involving the military analysis of specified causes, "combat interactions," which affect the various military units. To provide accurate analysis, the simulation or "war game" proceeds by short time intervals so that second order interactions can be neglected. The short time interval implies the need of much computation; i.e., the use of a computer and the objective is to set up a pattern of procedure which will produce a computerized war game. The general pattern begins with a specification of the Organic Military Units (OMU's) and the environmental characteristics which are to appear in the game. The next step is to list the "Combat Interactions," that is, the general causes which affect the units, for example, orders, supplies, terrain, enemy action, etc. We are interested in these general causes to the extent that they affect the numerical quantities which describe the OMU and its environment. These causes must be arranged in a sequence which will permit one to construct the formulas for the changes in the OMU quantities. These formulas are the major objective of the military analysis and other simulation aspects of the units are irrelevant. We indicate the way in which a logical analysis of the situation can be obtained which leads directly to a program structure.

TP2.7 A Model for Visual Target Detection from Aircraft, Frank D. Mason, *Hughes Aircraft Company, Aerospace Group, Aeronautical Systems Division, Culver City, California.*

The process of target detection from a moving aircraft is a function of: the physical and physiological factors which determine visibility range, given that the observer is looking at the target; the search pattern or strategy adopted by the observer; and the aircraft-to-target geometry as it varies with time. These factors are combined in a model from which may be derived distributions of targets de-tected in relation to the aircraft position, which can then be used to derive required turn rates, times available for ordnance delivery, and various effectiveness measures.

TP2.8 Consideration of Military Flexibility in Cost-Effectiveness Studies, E. O. BERDAHL, *Aerospace Corporation, San Bernardino Operations, San Bernardino California.*

One criticism by military commanders of operations research studies is that certain intrinsic values of military flexibility are not properly reflected in cost-effectiveness studies. This paper attempts to illustrate a possible approach whereby specific cost credits can be attributed to flexibility of a proposed system which can also accomplish a secondary mission in addition to its primary one. This credit artificially reduces the system cost by some fraction (perhaps 50%) of the cost which would be incurred if a separate vehicle were specifically procured to accomplish the secondary function. Full credit is not justified since the one system probably cannot do both missions simultaneously, and probably cannot accomplish either mission as well as systems optimally designed for each mission alone. On the other hand, long system procurement lead times require long range predictions of mission requirements which are often quite different than predicted when the system is finally delivered. Consequently, it is important that system operational flexibility should be encouraged in order to retain a mission capability at IOC in a world of rapidly changing requirements. This approach may be especially suited to the study of large aircraft platforms but can also be applied to the study of missile systems in some cases. The technique suggested would encourage the design of flexible systems by lowering the chargeable cost to the primary system being studied and thus increase its attractiveness index by lowering the cost-effectiveness ratio.

TP3.1 *On the Numerical Solution of Queueing Problems, MARCEL F. NEUTS, *Purdue University, Lafayette, Indiana.*

The usual assumptions in queueing theory are often made to enable the researcher to find global solutions in a closed mathematical form, however unwieldy. Explicit time dependent solutions are hard to obtain, even though a great deal of insight is gained in the structure and in the asymptotic behavior of the queue. In applications, however, numerical solutions are needed over a finite interval of time for queues with a finite waiting facility, with arrival and service processes whose distributions are empirical and not necessarily "nice." Here an alternate set of assumptions is needed, which can be used fruitfully in digital computation and should be plausible and general. We will discuss such assumptions and the resulting computational scheme. A few practical models will also be given as illustrations.

TP3.2 A Computerized Manpower Allocation System, WILLIAM L. MOOG and EARL D. LOWERY, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.* (Sponsored by JACOB A. WILLIAMS, *HEW, Social Security Administration, Baltimore, Maryland.*)

This paper discusses a conceptual manpower allocation system, which is designed to attain an optimum distribution of manpower resources throughout the

Social Security Administration District Office system, under both current and projected workload demand conditions. Yearly budget constraints require that the Administration make annual manpower projections. Workload inputs and staffing patterns are subject to daily random fluctuations, and yearly optimum levels occasionally result in office congestion. A design is proposed which utilizes linear models for yearly staffing projections and a computer simulation for analyzing operations with these staffs on a daily basis. Various staffing patterns which result from the mathematical formulations provide inputs for the simulator, while feedback from the simulator is used to readjust the linear models. This process is iterated until the budget, staffing, and queueing constraints are satisfied.

TP3.3 The Use of Monte Carlo Methods to Determine File Maintenance Criteria for an Automated Library Acquisitions System, GERALD J. LAZORICK, *Department of Industrial Engineering, State University of New York at Buffalo, Buffalo, New York.* (Sponsored by FERDINAND F. LEIMKUHLER, *Purdue University, Lafayette, Indiana.*)

This study investigates the relationship of the cost of producing information to the value derived from this information for an automated university library acquisitions system. The frequency of updating a magnetic tape file and producing a list from that file is investigated by developing a criterion function and evaluating various alternative decision rules by using a Monte Carlo model. Using the method of least squares, cost curves are developed from the data generated with the model and a minimum cost updating frequency is determined from these curves.

TP3.4 The Operations Research Library System, ERIC NEURON, *U. S. Naval Missile Center, Code 01-2, Point Mugu, California.* (Sponsored by LEWIS A. LEAKE, *Research Analysis Corporation, McLean, Virginia.*)

The "Operations Research Library System" is an attempt to create a viable information storage and retrieval system for the use of the Operations Research Group, Pacific Missile Range. The system is computer-aided, quite flexible, and postulates no limits on the range of subjects included, or the number of items which might be stored, other than the capabilities of the computer used. The system contains provisions for the necessary security classification controls, the information necessary for use as a source for report bibliographies, and is keyed to locate information in office files, libraries, or in the custody of individuals. Information storage methods are designed for the use of a small group of perhaps 20 individuals with listings originated by any member of the group and checked and organized by a single designated person. Retrieval of information is accomplished by calling for one to three "indicators" which can be chosen from an "Authority File." Actual operation is presently performed by an 8K 1401 system with 5 tape drives shared by many users. Operation is correspondingly slow, retrieval requiring about a day.

TP3.5 Design of School Bus Routes by Digital Computer, RITA M. NEWTON and WARREN H. THOMAS, *Department of Industrial Engineering, State University of New York at Buffalo, New York.* (Sponsored by FERDINAND F. LEIMKUHLER, *Purdue University, Lafayette, Indiana.*)

A practical procedure has been developed for generating school bus routes and schedules on a digital computer. This method has been used to solve an 80 bus stop problem in about 6 minutes on a 7090 computer. Routing is accomplished by a two step procedure. First, the shortest route for a bus of unlimited capacity to visit all stops is found. To solve this "Travelling Salesman" problem, an efficient heuristic procedure has been devised which yields near optimal solutions to realistic size problems. Next, this single route is partitioned to provide individual bus routes and schedules which satisfy bus capacity and passenger riding time constraints. This procedure is the outcome of the first in a continuing series of research efforts devoted to the practical solution of various aspects of the school bus scheduling problem.

TP3.6 Solutions of Certain Intractable Integer Linear Programming Problems, C. A. TRAUTH, JR. and R. E. WOOLSEY, *Sandia Corporation, Sandia Base, Albuquerque, New Mexico.* (Sponsored by STOUGHTON BELL, *Sandia Corporation, Albuquerque, New Mexico.*)

For certain classes of integer linear programming problems, the usual cutting-plane methods of solution due to Gomory become quite inefficient as the algorithm progresses. That is, the number of iterations needed to change the objective function value increases quite rapidly as a function of time. A method is presented which has consistently helped to overcome this difficulty. This study is empirical in nature, and supporting data involving five integer linear programming codes will be discussed.

TP3.7 Information Searching Behavior of Physicians, RICHARD W. TRUESWELL, *Industrial Engineering Program, School of Engineering, University of Massachusetts, Amherst, Massachusetts,* and ALBERT H. RUBENSTEIN, *Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois.*

This paper describes two studies made of certain aspects of the information searching behavior of physicians. An attempt is made to describe those parameters that would affect the development of an information retrieval system for physicians. The physicians studied were internal medicine specialists on the staff of a large metropolitan hospital and having some private practice. Sources of information were identified and the use of these sources by these physicians was studied. It is felt that this information is particularly pertinent to the development of information retrieval systems in medicine.

TP3.8 The Development of Estimating Equations for Computer Programming Costs, THOMAS FLEISHMAN, *Research and Technology Division, System Development Corporation, Santa Monica, California.* (Sponsored by GEORGES BRIGHAM, *Arthur Andersen and Company, Seattle, Washington.*)

Since 1964, the Programming Management Project at the System Development Corporation has been conducting research in the management of computer programming in an attempt to define standards and guidelines to aid managers in the estimation of computer programming costs. Specific emphasis has been on the development of linear equations for estimating costs. This Report reviews the current work to derive these equations, including the approach, the statistical methods, the characteristics of the data used and the results. The following stages constitute the analysis sequence: (a) definition of computer programming costs to be estimated in terms of cost measures (e.g., man months, computer hours), and cost factors (variables thought to affect costs) to be used as predictors; (b) design of a data collection questionnaire consisting of these cost measures and cost factors; (c) administration of the questionnaire to collect data on the program design, code and test phases of completed computer programming efforts; (d) examination and validation of the compiled data to correct anomalies by elimination or adjustment; and (e) application of multivariate statistical techniques, e.g., regression analysis, first to reduce the number of cost factors, and then to derive estimating relationships, in the form of linear equations, for costs in terms of cost factors. In addition to the analysis of the total sample, the size of the data base (169 points) permitted some preliminary subsample study. For example, data for programs written in machine-oriented language and procedure-oriented language were considered as two separate samples. The results of this work are presented.

TP3.9 An Analysis of Algorithms for the Traveling Salesman Problem, MANDELL BELLMORE and GEORGE L. NEMHAUSER, *Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland.*

Although there has been no major breakthrough in theory, there are presently available at least four somewhat efficient computational procedures for the traveling salesman problem. These are *dynamic programming, branch and bound,* and *two heuristic methods.* All of these algorithms are partial enumeration schemes designed for rapid calculation on high-speed digital computers. However, each of the enumerative approaches is rather different. We shall discuss the advantages and weaknesses of each of the algorithms and point out possible improvements and areas of further research.

WA1.1 *A Hospital Computer Network, JORDAN J. BARUCH, *Medinet, 100 Galen Street, Watertown, Massachusetts.*

It appears presently feasible to build a network of digital computers, each serving the medical community within a geographic region. Such a network has reliability requirements, fail soft requirements and cost requirements not generally encountered in normal digital systems. Furthermore, the balance of processing, file accessing and communication in the medical community differs significantly from that usually provided. A new ensemble of equipment and programs is being established with the aim of striking a balance among these requirements in serving medicine.

WA1.2 *Recent Developments in Some Technical Information Programs of the Federal Government, EZRA GLASER, *Public Health Service, Department of Health, Education, and Welfare, Bethesda, Maryland.*

This decade has witnessed a simultaneous intensification of demands for better organized technical information and the development of improved techniques for providing such services. At the present early stages of computer-assisted information systems there is more potential than accomplishment. Present status of several programs will be reviewed: chemical information, administrative-technical data in biomedical research, biological sciences. The total-system aspects of the problem will be emphasized, suggesting some performance characteristics that might be sought in all such information systems.

WA1.3 *A Visionary Recasts his Views on Information Retrieval, CALVIN N. MOOERS, *Rockford Research Institute, Inc., 140½ Mt. Auburn Street, Cambridge, Massachusetts.*

The field of "information retrieval" started some twenty years ago when simple mechanical tools were applied to assisting the intellect by making it easier to find written records. The general line of evolution since then has been toward the bigger, the more complicated, and the more costly. The current rash of "user studies" is but an indication that people have not been happy with the results obtained. What has gone wrong? What should be our course for the future? The new capabilities—vast storage, multi-user computers, reactive typewriters, displays, networks of communication, etc.—now apparently provide abilities in advance of our present conceptions for their use. The author's sad experiences in living with a computer-connected typewriter will be recounted. It is submitted that the new capabilities can and should be brought back to the assistance of the intellect. The key to a viable conception must emphasize the small, the local, the convenient, the reliable, and the personal aspects. There should be a balance between the load put on the paper book, the harnessed electron, and the human flesh. The synthesis to be achieved should become a trusted part of the total intellectual process which involves first stimulation and data gathering, followed by the creation, formulation, expression, and communication of ideas. The author will attempt to draw a picture, from his experience, of a simple but useful kind of facility that could become basic to these activities. Finally, "information retrieval" will be placed in perspective.

WA2.1 *Late Post Nuclear Attack Health Problems Study, R. S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*

This research is part of a study which estimates the magnitude of both the immediate and late post thermonuclear attack health problems to give guidance to the Public Health Service on preparedness planning. Of particular interest is the relative emphasis to be placed on planning to support attack injured vs. health problems which may occur later. The former case, analyzed by computer simulation, is not reported here. Inasmuch as the late postattack (D + one year) anticipated disease spectrum is very broad, the first step was to limit consideration to those conditions having the greatest life threat. The approach is to: (1) Use epidemiological models and historical disease statistics to select the few most significant (life threatening) health problems based on likely reservoir of infection, the parameters determining disease incidence, and case fatality rate. (2) Estimate the prevalence, fatalities, and health resource usage associated with these significant health problems under various health preparedness programs. (3) Compare effectiveness and resource requirements of (2) with previously analyzed programs to support prompt weapons effects and fallout casualties. (4) Estimate the effects of non-lethal radiation exposure; because of limited data, the "no-radiation" case is first analyzed. Radiation effects are ultimately incorporated using upper and lower bounds.

WA2.2 *Defining an Information System for Civil Defense Emergency Operations, E. R. Brooks, *Research Triangle Institute, Durham, North Carolina.*

For adequate planning and organizing for civil defense emergency operations, it is necessary to know what information is likely to be needed for decision making and how this information can be readily developed. This is difficult, for there is a wide range of situations requiring information that could exist at any particular location. However, it is possible to identify those types of actions that will be most important in meeting the objectives of civil defense It is also possible to identify the general composition of the staffs at various levels of government and the probable procedures for decision making. The information that is needed for decisions about each type of action and the possible sources of information (such as public shelters, police cars, and other operations centers) can then be qualitatively determined. Similarly, it is possible to specify the tasks performed by each staff element in developing and transmitting the required information. From the above definitions, requirements are derived for types and contents of messages from each likely source, and for file maintenance, message processing and display at each section of the operations center. In those cases where the assumed staff organization is not compatible with the derived requirements for information handling, the staff organization is redefined. While quantitative requirements for communications and data processing will depend largely upon the specific organization for which the information system is intended, the identification of types of messages, information processing, and decision making procedures will be useful for all civil defense organizations.

WA2.3 *Feasibility of Movement-to-Shelter Systems, Grace J. Kelleher, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

The feasibility and effectiveness of a movement-to-shelter (MTS) system of civil defense was examined by the Institute for Defense Analyses as part of its studies on Houston, Texas completed in 1965. Shelter sites were actually pinpointed in the land areas surrounding metropolitan Houston. An additional study on the feasibility of MTS systems was undertaken in 1966 and includes a representative sample of the 100 most populous urbanized areas of the U.S. The study focuses upon the availability of low density land areas which could be used for the siting and construction of fallout-resistant shelters to house city populations during times of crisis. Different levels (population percentages) of MTS are compared with alternative in-city defense systems from an effectiveness viewpoint. The analytic approach and results of the study will be presented.

WA2.4 *A History of Concepts of Emergency Operations for a Nuclear War Environment, Milton E. Jenkins, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

The introduction of nuclear weapons into warfare in the closing days of World

War II focused the attention of national planners on the need for new systems of passive defense to counter the new dimensions of the threat. The first studies of the subject were prepared by military authorities in the late 1940's, and continued interest in the subject led to the creation of civilian defense agencies by 1950. Many changes in the nature of the nuclear threat have occurred since then, and the resulting demands on the defense system have been reflected in changes in both organizations and programs over the years. The matter of particular concern here is only a portion of the total passive defense system, namely the organization required for efficient passive defense operations in the emergency period just before, during, and immediately after the attack. To a considerable degree, the environment in which such an organization must operate has changed relatively little since the nuclear weapon came into being. Increases in weapon yields have enlarged the areas over which weapon effects can occur, but blast, initial radiation, fires, and fallout radiation remain the same. This is a history of concepts that have attempted, through both the nature of the emergency operations organizations and the prescribed functions for the organizations, to minimize damage and loss of life due to the weapon effects. Both the military and the civil organizations have attempted to cope with the problem, and the efforts of both groups will be reviewed.

WA2.5 *Urban Casualty Prediction from a Nuclear Attack, L. WAYNE DAVIS, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

The Dikewood Corporation has been studying the problem of urban casualty prediction from a nuclear attack for several years under the sponsorship of the Office of Civil Defense. The first effort made use of the Joint Commission reports published by the Army Institute of Pathology on the effects of the atomic bombs dropped on Hiroshima and Nagasaki, Japan, in 1945. The thermal effect, blast, and initial nuclear radiation were separated for each shielding category and scaled individually to the megaton-yield range by the appropriate scaling laws, where the results were recombined. In a later study the building construction was sampled for various urban areas throughout the United States, and "typical" urban areas were developed. Casualty curves were then drawn for these areas using the previous results. More recently, an attempt has been made to improve the Japanese data source by coding and putting on magnetic tape information from over 35,000 case histories obtained from interviews in Hiroshima and Nagasaki. This information has greatly improved the data base for Japan and will allow the refinement of casualty prediction at the higher yields. Work is also underway to predict the medical load to be expected after a nuclear attack.

WA2.6 *German World War II Fire Casualties, JAMES A. KELLER, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

Ranges for estimated fire fatalities are developed for firestorms and group fires initiated by conventional weapons in German cities during World War II. Firestorm fatalities are estimated to vary between 4% and 20% of the population-at-hazard. Group fire fatalities are estimated to include up to 4% of the population-at-hazard. Limitations on extension of these estimates to the nuclear case and to U. S. cities are discussed.

WA2.7 *Emergency Operations Research at SDC, TERENCE P. HANEY, *System Development Corporation, Santa Monica, California.*

Over the past four years, System Development Corporation has conducted several interrelated research and development activities in the area of emergency operations. The most recent applied research efforts into emergency operations have dealt with the determination of information requirements for local level executive decision-making in a nuclear disaster. These experiments have involved city managers and their executive staffs from six cities in the 100,000 population class. A number of successful experiments indicated that the concept of simulation, developed earlier for use in Air Force development and training activities, could indeed be adapted to civil defense problems. The Emergency Operations Research Center was thus established. As a result of the executive staff experiments, a number of conclusions have become evident relating to the information required by local level executives in order for them to make adequate decisions in an emergency. Assuming the appropriateness of the inputs provided to stress the displays, this manner of presenting information was not very meaningful. It was found that the operations simulation technique, if properly applied, can be substantially beneficial as an applied research tool.

WA3 Application of Operations Research to Education (Panel). Session chaired by ALEX M. MOOD, *U. S. Office of Education, Washington, D. C.*

The panel will review and discuss current applications of analysis to educational problems. These include such things as input-output models of the educational system as a production process, flow models, models of individual institutions, evaluation models using regression models, analyses of education as a long term investment, program budgeting in education.

WP1.1 *Sensitivity of Optimal Inventory Policies, RAUL ALVAREZ, *Industrial Engineering Department, North Carolina State University, Raleigh, North Carolina.*

The sensitivity of the optimal cost of an inventory system to the various parameters involved in its determination is defined as follows:

$$S=\frac{(\text{change in cost})/(\text{cost})}{(\text{change in parameter})/(\text{parameter})}$$

or

$$S=\frac{\partial C_0}{\partial P}\cdot\frac{P}{C_0}$$

This is a unitless parameter. This paper shows how the sensitivity of the parameter is determined for a number of deterministic and probabilistic models. In almost all cases these are very simple expressions. With the aid of a computer, tables have been developed and graphs drawn that permit one to find, knowing the inventory model, the sensitivity of the cost to each of the parameters. The models investigated cover a small portion of the possible inventory systems encountered in actual situations. They are shown here with the purpose of showing how neat the expressions are and also how sensitivity behaves for different models.

WP1.2 *A Demonstration in the Use of Operations Research in the Improvement of a Hosiery Fabric, D. J. MOFFIE and GEORGE E. NICHOLSON, JR., *University of North Carolina, Chapel Hill, North Carolina.*

The major purpose of this project was to determine the optimum combination of factors for the production of a welt in ladies seamless hose which would meet the established physical and aethestic characteristics established by the Company. A composite second order design was used in the experiment. Ten stockings were prepared for each setting. These were evaluated by quality control personnel. A rating form which included dimensions of ribbiness, sleaziness, crinkles and overall appearance was used by the judges. Five variables were studied. These were: (1) welt length; (2) yarn type; (3) yarn twist; (4) setting temperature of the yarn; (5) cam setting. Optimum combinations were secured by a number of methods but the most practical solutions were secured through analysis of surfaces generated. The design was orthogonal. Findings supported experimentation conducted by the Company.

WP1.3 *Simulation Techniques Used as Aids for Decision Making, ALBERT W. BARTGES, *Systems and Procedures, Textile Fibers Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware.*

The Textile Fibers Department is one of the eleven operating departments of the Du Pont Company. This is a multi-plant and multi-fiber operation which is expanding rapidly. Quantitative answers are continuously needed for the evaluation of proposed courses of action. This presentation will deal with the application of linear programming and a machine and production scheduling computerized program as simulation techniques for attaining quantitative answers to alternate courses of action relative to costs, earnings, labor requirements, equipment utilization, inventory levels and product mix.

WP2.1 The Application of Simulation to Civil Defense System Development and Training, LARRY J. WELLS, *Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.* (Sponsored by ROBERT S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*)

A simulation model has been formulated to assist the Office of Civil Defense in the development of planning and operating criteria for Emergency Operating Centers and in the training of local government officials for the management of survival resources in a disaster environment. The model consists of two parts, a computer simulation and a real-time simulation. The inputs to the computer model are the physical characteristics of a city or county, the locations of critical resources, and postulated attack patterns. The computer develops a disaster environment and generates a time-phased series of emergency problems and informational reports. The computer outputs then become inputs to a real-time simulation in which local government officials are presented with a realistic test of their direction and control system. Real-time simulation enables an investigation of the dynamic responses of participants to a constantly changing environment. An analysis of the simulation provides data on the effectiveness of various direction and control system configurations, information processing techniques, and decision-making procedures. Because of the speed, simplicity, and economy with which a realistic disaster environment can be simulated on a computer the model is applicable for training as well as system development.

WP2.2 NRDL Target Vulnerability Studies as Applied to the Civil Defense Program, JUNE BREVDY, *Countermeasures Evaluation Branch, U. S. Naval Radiological Defense Laboratory, San Francisco, California.*

The Office of Civil Defense (OCD) is sponsoring a study at NRDL in which the focus will be on predicting the postattack survivability of a city. This study is based on previous work for a Navy project (the Target Vulnerability Studies) and will have the same general objectives: (1) to provide a means for estimating, rapidly and consistently, the effects of a widespread continental nuclear attack on facilities and personnel; (2) to provide an evaluation of the capability of these effects to interfere with operations; (3) to provide estimates of the time required for emergency recovery; and (4) to make recommendations for preattack actions that could alleviate the degrading effect of the attack upon designated postattack functions. The paper will discuss the approach that was designed to analyze installations of interest and the model that was constructed to provide results to satisfy the above objectives. It will also discuss the application of the method and the models to the OCD project.

WP2.3 A System Design for Developing Fallout Shelter in New Construction, E. L. HILL, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by ROBERT S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*)

There is a need to develop dual purpose fallout shelter in addition to that already identified in the National Fallout Shelter Survey. An incentives program is under consideration under which a building owner would be offered a small financial incentive to include fallout shelter beyond that inherent in "typical" designs. Additional shelter could be had by employing no cost or low cost design modification ("slanting") already developed by the Office of Civil Defense. The purpose of the study reported here is to evaluate alternative incentive programs in terms of fallout shelter added to the inventory beyond that which would have appeared spontaneously, and to estimate the costs. The research has been approached through: (1) analyzing existing structures to estimate cost and yield of added spaces through slanting for various building classes; (2) fictitious building analysis as in (1); (3) correlation of past construction history from F. W. Dodge Company reports to forecast construction rates of eligible structures in shelter deficit areas. Many additional factors are considered including: impact on building owners who have already licensed their buildings for public shelter; fringe benefits of an incentives program such as increased public awareness; the management system required, etc. The output of the study are recommended plans: (1) a program to maximize information obtained in a pilot program; (2) a program to maximize shelter added in the event that the pilot program is bypassed.

WP2.4 An Algorithm for Maximizing Cost Effectiveness of Civil Defense Shelter Development Programs, P. S. McMullan and Stanley Trustman, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by Robert S. Titchen, *Research Triangle Institute, Durham, North Carolina.*)

Civil Defense shelter development planners in the Office of Civil Defense seek maximum cost effectiveness. To this end, a computerized model has been developed for optimizing civil defense shelter development programs which build on the current National Fallout Shelter Survey. The model is risk-oriented: with a specified attack, a probability of survival is calculated for existing shelter and new shelter options. Vulnerability to both blast and fallout is considered. Input data are cost, personnel vulnerability, number of shelter spaces for both existing shelter and new shelter options, and a budget. The model then assigns population to new shelter options in a manner to maximize survivors (or uninjured survivors) for the specified budget. The output is the optimum shelter development program. Curves of survivors added, and marginal costs, as a function of budget are also obtained by varying the budget constraint. Because existing algorithms cannot handle problems of the size encountered in national analyses, a new optimizing algorithm was developed and programmed. It is suitable for transportation-type problems having a special cost matrix structure; the costs must be ordered to vary monotonically within each column.

WP2.5 An Analytical Technique for Urban Casualty Estimation from Multiple Nuclear Weapons, J. J. Hunter, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by Robert S. Titchen, *Research Triangle Institute, Durham, North Carolina.*)

Currently, national vulnerability analyses of urban populations are made by assessing small grids. For many purposes, this procedure is too costly in computer time. As a tool for sensitivity analysis of national vulnerability assessment methods, an analytical technique has been developed which estimates casualties from multiple nuclear weapons. This is done by describing the urban population by a circularly symmetric spatial density function. This density function may be readily varied to describe alternative shelter postures, evacuation, etc., and for parametric analyses of many kinds. The input data are: (1) coordinates of the DGZ's and of the population center; (2) weapon yields, burst heights, shielding posture, and corresponding casualty curves; (3) CEP; and (4) two spatial population distribution parameters. The model has been programmed in FORTRAN and is now in use in sensitivity analyses for the Office of Civil Defense.

WP3.1 *The Analytic Models for Implementing the Economic Impact Studies for the Northeast Corridor Transportation Project, S. H. Putnam, *CONSAD Research Corporation, Pittsburgh, Pennsylvania.*

The Northeast Corridor Transportation Project being conducted by the U. S. Department of Commerce has been defined as a comprehensive regional transportation planning activity to determine passenger and freight requirements in that region to 1980 and beyond. As part of the total Corridor Project, CONSAD is developing a set of models to project and evaluate the economic and demographic impacts of changes in the regional transportation network. The model system is comprised of three basic submodels: 1) inter-regional, inter-industry model, 2) intra-regional allocation model, and 3) impact evaluation model. This paper discusses the theoretic and pragmatic considerations which determined the design of each of the three sub-models, the problems entailed in calibrating the models, and the strategy and progress of the effort to implement them.

WP3.2 *Econometric Study of the Urban Traffic, JACQUES FEDERWISCH and PIERRE VAN LEEUW, *Société de Recherche Opérationnelle et d'Economie Appliquée, Brussles 5, Belgium.*

The mathematical models of urban traffic are numerous and generally analyse the volume and the nature of the movements as well as the loss of time (estimated either in time or monetary units). The authors have introduced two complementary traffic sub-models (the descriptive and the explanatory one) and a new variable called displacements entropy, measuring in a defective and uniform way for all the transportation models the infrastructure possibilities existing at a given origin for reaching a given destination. The general model, completed in this manner by the description of the infrastructures making those displacements possible, brings a solution to all traffic problems in an exhaustive way. The model is also based on the prospective evolution of displacements. All the aspects can thus be studied (gain of time, cost of infrastructure, compared advantages, investments return, etc.). This model was adjusted and tested during two general urban traffic studies, which took place in Antwerp and Ghent, Belgium, including their respective suburbs. It led to the most appropriate layout for an intended underground railway network.

WP3.3 *An Investigation of Aircraft Collision Risks over the North Atlantic, LEONARD STACHTCHENKO, *Unica Research Company, Montreal, Quebec, Canada.*

This paper reviews the navigation errors of westbound aircraft traveling over assigned tracks of the North Atlantic regions. These errors have been measured by radar from the Canadian North Atlantic Air Traffic Center at Gander, Newfoundland. An analysis of the errors shows that these are not Gaussian. A theory is developed to evaluate the probability of collision over the North Atlantic region, with consideration being given to the effects of lateral separation of pre-assigned tracks.

WP3.4 *A Transportation Program for Filling Idle Classrooms in Los Angeles, T. A. BROWN, *The RAND Corporation, Santa Monica, California.*

During the 1965–1966 school year more than 25,000 elementary school children were on short, double or extended sessions in Los Angeles; at the same time there were 327 idle elementary classrooms in Los Angeles. In an effort to relieve this situation and at the same time alleviate defacto segregation the Transport-A-Child Foundation proposed last spring that the Los Angeles School Board provide transportation for more than 2000 children outside their immediate neighborhoods. Operations analysts designed a program which would cost about 67¢ per child per day. This talk will explain how this was done and mention some of the political consequences of the proposal.

TP1.1 *Operations Research on Police Problems in the United Kingdom, A. G. McDonald, *Scientific Adviser's Branch, Home Office, London, England.*

A review of projects undertaken by the OR group in the Home Office will be presented. Some of them are: assessment of patrol and intelligence operations; development of methods of crime detection; examination of information flow; equipment evaluation; resource allocation.

TP1.2 *Scheduling of the Patrol Force in Alexandria, Virginia, F. R. Frola, R. E. Gordon, and S. S. Richmond, *North American Aviation, Inc., 1735 I Street, N. W., Washington, D. C.*

This paper is a report on a joint project involving the City of Alexandria, Virginia, and North American Aviation, Inc., to investigate the utilization of the police patrol forces. Specifically, the objective of the study is to generate a profile of the time-demand for police services and to schedule the available patrol force to meet this demand. Detailed operational data was collected over a 6-month period and subjected to statistical analysis, including (1) Pearson curve fitting to obtain the service-time distribution of police calls, (2) analysis of variance to estimate daily and seasonal fluctuations, and (3) measures of the time spent by patrolmen in various activities. An experiment is being designed to estimate the effects of preventive patrol on crime. Such knowledge will enable the optimum allocation of the time available for preventive patrol. In particular, this information will complete the demand-for-service profile and thereby permit the scheduling part of the problem to be accomplished. A non-linear integer programming representation of the scheduling problem can be used to achieve the scheduling, once the above relationships involving preventable crime are ascertained. As an interim step a graphical approximation of the solution has been obtained by estimating the class of preventable crimes and by ignoring the effects of patrol on these crimes.

TP1.3 *The Design of an Emergency Road Service System with Implications for the Deployment of Police Forces, Michael Leyzorek, *25 N. Washington Street, Port Washington, New York.*

There is an analogy between problems of operating an emergency road service system and those of deploying effectively a police force. In both cases service demands from the public arise randomly. However, there is a probability distribution describing the likelihood that a given number of service demands will occur at a given time and place. The problem is to match numbers and locations of service personnel and vehicles to numbers and locations of service demands and to provide a desired standard of performance. A city is often classified into geographic areas, each of which becomes the responsibility of an element of the service force; consequently the available force is frequently idle because of the random demand pattern. This paper describes an alternative approach in which a completely mobile force controlled from a central station supplies the service requirements by shifting the available force from area to area in accordance with the changing demand pattern as previously analyzed, thus obtaining far better utilization of available service resources and providing any desired standard of performance. In designing a police system it is essential to apply a suitable priority to various services to insure that correct allocation has been made of police resources.

TP1.4 *A Model of Social Conflict, HERBERT K. WEISS, *Litton Data Systems Division, 8000 Woodley Avenue, Van Nuys, California.*

Crime data indicates a generally higher per capita crime rate in large cities than in small cities. A Maxwellian model of criminal activity is hypothesized, leading to the conjecture that per capita crime rate (other factors being equal) will be proportional to population density. The model is next modified to include the deterrent effect of police operations. A comparison with reported crime rates for individual cities is presented, and some projections are made of the effect of increased urbanization and the changing age distribution of the population on growth in the crime rate. Flow diagrams are presented for the interaction between the crime prevention and law enforcement process and the crime rate. The principal parameters are further developed in terms of measurable characteristics of the conflict process. The effect of scale of organization is discussed. Some general conclusions are developed regarding measures of effectiveness and cost-effectiveness trades.

TP2.1 Fighter Analysis—Tactical Air Combat (FANTAC), CHARLES B. WHALEY, *Los Angeles Division, North American Aviation, Inc., International Airport, Los Angeles, California.* (Sponsored by WENDELL J. THOMPSON, *North American Aviation, Los Angeles, California.*)

The recent emphasis on air-to-air combat has resulted in the development of a digital computer simulation model called FANTAC to simulate a three dimensional, one-on-one-fighter-fighter duel. This development effort was sponsored by the Directorate of Studies and Analysis, Headquarters USAF (formerly known as the Air Battle Analysis Center). FANTAC models the detection, tactics, and kill portions of the duel. In the detection area the capability exists to simulate the performance of radar, infrared, and visual sensor systems. In the kill area guns, radar and infrared guided missiles, and unguided rockets can be simulated. The tactics area is composed of three parts, viz. (1) a "decision tree" to select a maneuver (hard turn, yo-yo, etc.) based upon the situation existing at the moment. (2) a series of subroutines to compute the changes in an aircraft's control variables (roll rate, pitch rate, and thrust) to effect the desired maneuvers, and (3) six degree-of-freedom aerodynamic equations of motion to calculate the trajectories of the duelists. All maneuvers occur in three dimensions. FANTAC contains two distinct logic loops in that each aircraft reacts to the position and capabilities of the other. FANTAC may be used to evaluate sensor system capabilities, aircraft performance capabilities, weapon capabilities, and tactics.

TP2.2 An Optimum Missile Test Program Based on Cost-Effectiveness, J. SMILLIE and F. WERTHEIMER, *Vitro Laboratories, Division of Vitro Corporation of America, 200 Pleasant Valley Way, West Orange, New Jersey.* (Sponsored by FRANCIS JOSEPH FELIX, *Vitro Laboratories*).

This paper describes a methodology, based on cost-effectiveness concepts, with which to establish policy guidelines for attaining an optimum missile test program. The methodology includes consideration of a) a missile inventory of varying missile ages and missile capabilities; b) a military requirement to keep a fixed price level on ready alert; c) an on-going practice of cyclic inspection and repair; d) an on-going program of missile testing. The methodology centers about the formulation of a risk function, expressed in terms of the four considerations listed above and their associated cost. The variations of this function are examined, and its sensitivity to the number of missiles tested is determined. Previous efforts in this field have been mainly concerned with the evolution of an optimum test policy when only random failures appear. The present paper considers the entry of failure modes as the result of missile ageing. The problem of detecting the entry of such a mode is discussed, because the optimum test policy is strongly dependent upon such detection, and the time after entry when failure mode detection occurs. The paper also deals with the possibility of multiple failure modes. Using the risk function, the methodology provides decision criteria on a cost-effectiveness basis for an optimum test policy, for the repair/replace policy, and for a missile procurement policy.

TP2.3 A Cost-Effective Method to Determine Ground Survivability of Strategic Aircraft, SAMUEL C. COLWELL, *The Boeing Company, Commercial Airplane Division, Renton, Washington.*

This paper is concerned with determining a strategy which will allow an effective retaliatory force of strategic aircraft to survive an enemy surprise attack on the United States. The ways to ensure this survival include aircraft dispersal, hardening, level of alert and combinations of these variables. The study develops the analysis which will determine a ground survivability policy based on the above variables and which minimizes the cost of purchasing, operating and maintaining the aircraft while ensuring a set survivability level. The model allows the user to perform a parametric analysis to determine a cost-effective allocation of the number of bases, the number of aircraft per base, the degree of hardening, etc., and takes into account such factors as warning time, reaction time, level of attack and aiming errors.

TP2.4 A Procedure for Aiding Strategic Aircraft Route Planning, SAUL I. GASS, JOHN R. NORTON, and DAVID B. WEBSTER, *IBM Federal Systems Division, Federal Systems Center, Bethesda, Maryland.*

The problem of determining recommended target approach paths for certain strategic aircraft was approached as that of finding a shortest route through a network. That is, an aircraft is assumed to approach a target by flying over a sequence of grid points. Associated with each grid point is a numerical value proportional to the risk involved in flying across it, the risk being a function of its coverage by defensive weapons. A sequence of points leading to the target and return constitutes a possible route, and the risk involved in flying this route is assumed to be proportional to the sum of the risks associated with each point on the route. Since the problem involved a large number of nodes, it was highly important from a computational point of view regarding computer running time that an acyclic network be developed which would also contain all reasonable flight paths. This permitted the set of nodes to be processed once and the shortest (minimum risk) route determined by a single pass through by the computer.

TP2.5 Altitude Flight Gains and Losses, H. A. Ralles, *Dept. 3621, Zone 35, Northrop Norair, 3901 West Broadway, Hawthorne, California.*

The threat of antiaircraft fire to low-flying aircraft decreases markedly as the aircraft flies closer to the terrain, but the price of this margin of safety is a correspondingly increased risk of flying into the ground. A model is presented to evaluate the two risks as a function of aircraft speed and altitude above the terrain mean for varying degrees of terrain roughness. Since terrain roughness can be characterized statistically, the probabilities of terrain prominences can be used to evaluate line-of-sight probability, and probability of aircraft impact with the terrain. The utility of the model is shown by an illustrative example.

TP2.6 A Pattern of Military Analysis for a Computerized Fixed Increment War Game, F. J. Murray, W. E. Sewell, and K. A. Heimes, *Special Research in Numerical Analysis, Duke University, Durham, North Carolina.* (Sponsored by George E. Nicholson, Jr., *University of North Carolina, Chapel Hill, North Carolina.*)

The simulation of a military operation which is normally part of war gaming is obtained by a procedure involving the military analysis of specified causes, "combat interactions," which affect the various military units. To provide accurate analysis, the simulation or "war game" proceeds by short time intervals so that second order interactions can be neglected. The short time interval implies the need of much computation; i.e., the use of a computer and the objective is to set up a pattern of procedure which will produce a computerized war game. The general pattern begins with a specification of the Organic Military Units (OMU's) and the environmental characteristics which are to appear in the game. The next step is to list the "Combat Interactions," that is, the general causes which affect the units, for example, orders, supplies, terrain, enemy action, etc. We are interested in these general causes to the extent that they affect the numerical quantities which describe the OMU and its environment. These causes must be arranged in a sequence which will permit one to construct the formulas for the changes in the OMU quantities. These formulas are the major objective of the military analysis and other simulation aspects of the units are irrelevant. We indicate the way in which a logical analysis of the situation can be obtained which leads directly to a program structure.

TP2.7 A Model for Visual Target Detection from Aircraft, Frank D. Mason, *Hughes Aircraft Company, Aerospace Group, Aeronautical Systems Division, Culver City, California.*

The process of target detection from a moving aircraft is a function of: the physical and physiological factors which determine visibility range, given that the observer is looking at the target; the search pattern or strategy adopted by the observer; and the aircraft-to-target geometry as it varies with time. These factors are combined in a model from which may be derived distributions of targets de-tected in relation to the aircraft position, which can then be used to derive required turn rates, times available for ordnance delivery, and various effectiveness measures.

TP2.8 Consideration of Military Flexibility in Cost-Effectiveness Studies, E. O. Berdahl, *Aerospace Corporation, San Bernardino Operations, San Bernardino California.*

One criticism by military commanders of operations research studies is that certain intrinsic values of military flexibility are not properly reflected in cost-effectiveness studies. This paper attempts to illustrate a possible approach whereby specific cost credits can be attributed to flexibility of a proposed system which can also accomplish a secondary mission in addition to its primary one. This credit artificially reduces the system cost by some fraction (perhaps 50%) of the cost which would be incurred if a separate vehicle were specifically procured to accomplish the secondary function. Full credit is not justified since the one system probably cannot do both missions simultaneously, and probably cannot accomplish either mission as well as systems optimally designed for each mission alone. On the other hand, long system procurement lead times require long range predictions of mission requirements which are often quite different than predicted when the system is finally delivered. Consequently, it is important that system operational flexibility should be encouraged in order to retain a mission capability at IOC in a world of rapidly changing requirements. This approach may be especially suited to the study of large aircraft platforms but can also be applied to the study of missile systems in some cases. The technique suggested would encourage the design of flexible systems by lowering the chargeable cost to the primary system being studied and thus increase its attractiveness index by lowering the cost-effectiveness ratio.

TP3.1 *On the Numerical Solution of Queueing Problems, Marcel F. Neuts, *Purdue University, Lafayette, Indiana.*

The usual assumptions in queueing theory are often made to enable the researcher to find global solutions in a closed mathematical form, however unwieldy. Explicit time dependent solutions are hard to obtain, even though a great deal of insight is gained in the structure and in the asymptotic behavior of the queue. In applications, however, numerical solutions are needed over a finite interval of time for queues with a finite waiting facility, with arrival and service processes whose distributions are empirical and not necessarily "nice." Here an alternate set of assumptions is needed, which can be used fruitfully in digital computation and should be plausible and general. We will discuss such assumptions and the resulting computational scheme. A few practical models will also be given as illustrations.

TP3.2 A Computerized Manpower Allocation System, William L. Moog and Earl D. Lowery, *Social Security Administration, Department of Health, Education, and Welfare, Baltimore, Maryland.* (Sponsored by Jacob A. Williams, *HEW, Social Security Administration, Baltimore, Maryland.*)

This paper discusses a conceptual manpower allocation system, which is designed to attain an optimum distribution of manpower resources throughout the

Social Security Administration District Office system, under both current and projected workload demand conditions. Yearly budget constraints require that the Administration make annual manpower projections. Workload inputs and staffing patterns are subject to daily random fluctuations, and yearly optimum levels occasionally result in office congestion. A design is proposed which utilizes linear models for yearly staffing projections and a computer simulation for analyzing operations with these staffs on a daily basis. Various staffing patterns which result from the mathematical formulations provide inputs for the simulator, while feedback from the simulator is used to readjust the linear models. This process is iterated until the budget, staffing, and queueing constraints are satisfied.

TP3.3 The Use of Monte Carlo Methods to Determine File Maintenance Criteria for an Automated Library Acquisitions System, GERALD J. LAZORICK, *Department of Industrial Engineering, State University of New York at Buffalo, Buffalo, New York.* (Sponsored by FERDINAND F. LEIMKUHLER, *Purdue University, Lafayette, Indiana.*)

This study investigates the relationship of the cost of producing information to the value derived from this information for an automated university library acquisitions system. The frequency of updating a magnetic tape file and producing a list from that file is investigated by developing a criterion function and evaluating various alternative decision rules by using a Monte Carlo model. Using the method of least squares, cost curves are developed from the data generated with the model and a minimum cost updating frequency is determined from these curves.

TP3.4 The Operations Research Library System, ERIC NEURON, *U. S. Naval Missile Center, Code 01-2, Point Mugu, California.* (Sponsored by LEWIS A. LEAKE, *Research Analysis Corporation, McLean, Virginia.*)

The "Operations Research Library System" is an attempt to create a viable information storage and retrieval system for the use of the Operations Research Group, Pacific Missile Range. The system is computer-aided, quite flexible, and postulates no limits on the range of subjects included, or the number of items which might be stored, other than the capabilities of the computer used. The system contains provisions for the necessary security classification controls, the information necessary for use as a source for report bibliographies, and is keyed to locate information in office files, libraries, or in the custody of individuals. Information storage methods are designed for the use of a small group of perhaps 20 individuals with listings originated by any member of the group and checked and organized by a single designated person. Retrieval of information is accomplished by calling for one to three "indicators" which can be chosen from an "Authority File." Actual operation is presently performed by an 8K 1401 system with 5 tape drives shared by many users. Operation is correspondingly slow, retrieval requiring about a day.

TP3.5 Design of School Bus Routes by Digital Computer, RITA M. NEWTON and WARREN H. THOMAS, *Department of Industrial Engineering, State University of New York at Buffalo, New York.* (Sponsored by FERDINAND F. LEIMKUHLER, *Purdue University, Lafayette, Indiana.*)

A practical procedure has been developed for generating school bus routes and schedules on a digital computer. This method has been used to solve an 80 bus stop problem in about 6 minutes on a 7090 computer. Routing is accomplished by a two step procedure. First, the shortest route for a bus of unlimited capacity to visit all stops is found. To solve this "Travelling Salesman" problem, an efficient heuristic procedure has been devised which yields near optimal solutions to realistic size problems. Next, this single route is partitioned to provide individual bus routes and schedules which satisfy bus capacity and passenger riding time constraints. This procedure is the outcome of the first in a continuing series of research efforts devoted to the practical solution of various aspects of the school bus scheduling problem.

TP3.6 Solutions of Certain Intractable Integer Linear Programming Problems, C. A. TRAUTH, JR. and R. E. WOOLSEY, *Sandia Corporation, Sandia Base, Albuquerque, New Mexico.* (Sponsored by STOUGHTON BELL, *Sandia Corporation, Albuquerque, New Mexico.*)

For certain classes of integer linear programming problems, the usual cutting-plane methods of solution due to Gomory become quite inefficient as the algorithm progresses. That is, the number of iterations needed to change the objective function value increases quite rapidly as a function of time. A method is presented which has consistently helped to overcome this difficulty. This study is empirical in nature, and supporting data involving five integer linear programming codes will be discussed.

TP3.7 Information Searching Behavior of Physicians, RICHARD W. TRUESWELL, *Industrial Engineering Program, School of Engineering, University of Massachusetts, Amherst, Massachusetts,* and ALBERT H. RUBENSTEIN, *Department of Industrial Engineering and Management Sciences, Northwestern University, Evanston, Illinois.*

This paper describes two studies made of certain aspects of the information searching behavior of physicians. An attempt is made to describe those parameters that would affect the development of an information retrieval system for physicians. The physicians studied were internal medicine specialists on the staff of a large metropolitan hospital and having some private practice. Sources of information were identified and the use of these sources by these physicians was studied. It is felt that this information is particularly pertinent to the development of information retrieval systems in medicine.

TP3.8 The Development of Estimating Equations for Computer Programming Costs, THOMAS FLEISHMAN, *Research and Technology Division, System Development Corporation, Santa Monica, California.* (Sponsored by GEORGES BRIGHAM, *Arthur Andersen and Company, Seattle, Washington.*)

Since 1964, the Programming Management Project at the System Development Corporation has been conducting research in the management of computer programming in an attempt to define standards and guidelines to aid managers in the estimation of computer programming costs. Specific emphasis has been on the development of linear equations for estimating costs. This Report reviews the current work to derive these equations, including the approach, the statistical methods, the characteristics of the data used and the results. The following stages constitute the analysis sequence: (a) definition of computer programming costs to be estimated in terms of cost measures (e.g., man months, computer hours), and cost factors (variables thought to affect costs) to be used as predictors; (b) design of a data collection questionnaire consisting of these cost measures and cost factors; (c) administration of the questionnaire to collect data on the program design, code and test phases of completed computer programming efforts; (d) examination and validation of the compiled data to correct anomalies by elimination or adjustment; and (e) application of multivariate statistical techniques, e.g., regression analysis, first to reduce the number of cost factors, and then to derive estimating relationships, in the form of linear equations, for costs in terms of cost factors. In addition to the analysis of the total sample, the size of the data base (169 points) permitted some preliminary subsample study. For example, data for programs written in machine-oriented language and procedure-oriented language were considered as two separate samples. The results of this work are presented.

TP3.9 An Analysis of Algorithms for the Traveling Salesman Problem, MANDELL BELLMŌRE and GEORGE L. NEMHAUSER, *Department of Operations Research and Industrial Engineering, The Johns Hopkins University, Baltimore, Maryland.*

Although there has been no major breakthrough in theory, there are presently available at least four somewhat efficient computational procedures for the traveling salesman problem. These are *dynamic programming*, *branch and bound*, and *two heuristic methods.* All of these algorithms are partial enumeration schemes designed for rapid calculation on high-speed digital computers. However, each of the enumerative approaches is rather different. We shall discuss the advantages and weaknesses of each of the algorithms and point out possible improvements and areas of further research.

WA1.1 *A Hospital Computer Network, JORDAN J. BARUCH, *Medinet, 100 Galen Street, Watertown, Massachusetts.*

It appears presently feasible to build a network of digital computers, each serving the medical community within a geographic region. Such a network has reliability requirements, fail soft requirements and cost requirements not generally encountered in normal digital systems. Furthermore, the balance of processing, file accessing and communication in the medical community differs significantly from that usually provided. A new ensemble of equipment and programs is being established with the aim of striking a balance among these requirements in serving medicine.

WA1.2 *Recent Developments in Some Technical Information Programs of the Federal Government, EZRA GLASER, *Public Health Service, Department of Health, Education, and Welfare, Bethesda, Maryland.*

This decade has witnessed a simultaneous intensification of demands for better organized technical information and the development of improved techniques for providing such services. At the present early stages of computer-assisted information systems there is more potential than accomplishment. Present status of several programs will be reviewed: chemical information, administrative-technical data in biomedical research, biological sciences. The total-system aspects of the problem will be emphasized, suggesting some performance characteristics that might be sought in all such information systems.

WA1.3 *A Visionary Recasts his Views on Information Retrieval, CALVIN N. MOOERS, *Rockford Research Institute, Inc., 140½ Mt. Auburn Street, Cambridge, Massachusetts.*

The field of "information retrieval" started some twenty years ago when simple mechanical tools were applied to assisting the intellect by making it easier to find written records. The general line of evolution since then has been toward the bigger, the more complicated, and the more costly. The current rash of "user studies" is but an indication that people have not been happy with the results obtained. What has gone wrong? What should be our course for the future? The new capabilities—vast storage, multi-user computers, reactive typewriters, displays, networks of communication, etc.—now apparently provide abilities in advance of our present conceptions for their use. The author's sad experiences in living with a computer-connected typewriter will be recounted. It is submitted that the new capabilities can and should be brought back to the assistance of the intellect. The key to a viable conception must emphasize the small, the local, the convenient, the reliable, and the personal aspects. There should be a balance between the load put on the paper book, the harnessed electron, and the human flesh. The synthesis to be achieved should become a trusted part of the total intellectual process which involves first stimulation and data gathering, followed by the creation, formulation, expression, and communication of ideas. The author will attempt to draw a picture, from his experience, of a simple but useful kind of facility that could become basic to these activities. Finally, "information retrieval" will be placed in perspective.

WA2.1 *Late Post Nuclear Attack Health Problems Study, R. S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*

This research is part of a study which estimates the magnitude of both the immediate and late post thermonuclear attack health problems to give guidance to the Public Health Service on preparedness planning. Of particular interest is the relative emphasis to be placed on planning to support attack injured vs. health problems which may occur later. The former case, analyzed by computer simulation, is not reported here. Inasmuch as the late postattack (D + one year) anticipated disease spectrum is very broad, the first step was to limit consideration to those conditions having the greatest life threat. The approach is to: (1) Use epidemiological models and historical disease statistics to select the few most significant (life threatening) health problems based on likely reservoir of infection, the parameters determining disease incidence, and case fatality rate. (2) Estimate the prevalence, fatalities, and health resource usage associated with these significant health problems under various health preparedness programs. (3) Compare effectiveness and resource requirements of (2) with previously analyzed programs to support prompt weapons effects and fallout casualties. (4) Estimate the effects of non-lethal radiation exposure; because of limited data, the "no-radiation" case is first analyzed. Radiation effects are ultimately incorporated using upper and lower bounds.

WA2.2 ***Defining an Information System for Civil Defense Emergency Operations,** E. R. Brooks, *Research Triangle Institute, Durham, North Carolina.*

For adequate planning and organizing for civil defense emergency operations, it is necessary to know what information is likely to be needed for decision making and how this information can be readily developed. This is difficult, for there is a wide range of situations requiring information that could exist at any particular location. However, it is possible to identify those types of actions that will be most important in meeting the objectives of civil defense It is also possible to identify the general composition of the staffs at various levels of government and the probable procedures for decision making. The information that is needed for decisions about each type of action and the possible sources of information (such as public shelters, police cars, and other operations centers) can then be qualitatively determined. Similarly, it is possible to specify the tasks performed by each staff element in developing and transmitting the required information. From the above definitions, requirements are derived for types and contents of messages from each likely source, and for file maintenance, message processing and display at each section of the operations center. In those cases where the assumed staff organization is not compatible with the derived requirements for information handling, the staff organization is redefined. While quantitative requirements for communications and data processing will depend largely upon the specific organization for which the information system is intended, the identification of types of messages, information processing, and decision making procedures will be useful for all civil defense organizations.

WA2.3 ***Feasibility of Movement-to-Shelter Systems,** Grace J. Kelleher, *Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.*

The feasibility and effectiveness of a movement-to-shelter (MTS) system of civil defense was examined by the Institute for Defense Analyses as part of its studies on Houston, Texas completed in 1965. Shelter sites were actually pinpointed in the land areas surrounding metropolitan Houston. An additional study on the feasibility of MTS systems was undertaken in 1966 and includes a representative sample of the 100 most populous urbanized areas of the U.S. The study focuses upon the availability of low density land areas which could be used for the siting and construction of fallout-resistant shelters to house city populations during times of crisis. Different levels (population percentages) of MTS are compared with alternative in-city defense systems from an effectiveness viewpoint. The analytic approach and results of the study will be presented.

WA2.4 ***A History of Concepts of Emergency Operations for a Nuclear War Environment,** Milton E. Jenkins, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

The introduction of nuclear weapons into warfare in the closing days of World

War II focused the attention of national planners on the need for new systems of passive defense to counter the new dimensions of the threat. The first studies of the subject were prepared by military authorities in the late 1940's, and continued interest in the subject led to the creation of civilian defense agencies by 1950. Many changes in the nature of the nuclear threat have occurred since then, and the resulting demands on the defense system have been reflected in changes in both organizations and programs over the years. The matter of particular concern here is only a portion of the total passive defense system, namely the organization required for efficient passive defense operations in the emergency period just before, during, and immediately after the attack. To a considerable degree, the environment in which such an organization must operate has changed relatively little since the nuclear weapon came into being. Increases in weapon yields have enlarged the areas over which weapon effects can occur, but blast, initial radiation, fires, and fallout radiation remain the same. This is a history of concepts that have attempted, through both the nature of the emergency operations organizations and the prescribed functions for the organizations, to minimize damage and loss of life due to the weapon effects. Both the military and the civil organizations have attempted to cope with the problem, and the efforts of both groups will be reviewed.

WA2.5 *Urban Casualty Prediction from a Nuclear Attack, L. Wayne Davis, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

The Dikewood Corporation has been studying the problem of urban casualty prediction from a nuclear attack for several years under the sponsorship of the Office of Civil Defense. The first effort made use of the Joint Commission reports published by the Army Institute of Pathology on the effects of the atomic bombs dropped on Hiroshima and Nagasaki, Japan, in 1945. The thermal effect, blast, and initial nuclear radiation were separated for each shielding category and scaled individually to the megaton-yield range by the appropriate scaling laws, where the results were recombined. In a later study the building construction was sampled for various urban areas throughout the United States, and "typical" urban areas were developed. Casualty curves were then drawn for these areas using the previous results. More recently, an attempt has been made to improve the Japanese data source by coding and putting on magnetic tape information from over 35,000 case histories obtained from interviews in Hiroshima and Nagasaki. This information has greatly improved the data base for Japan and will allow the refinement of casualty prediction at the higher yields. Work is also underway to predict the medical load to be expected after a nuclear attack.

WA2.6 *German World War II Fire Casualties, James A. Keller, *The Dikewood Corporation, 4805 Menaul Blvd., N.E., Albuquerque, New Mexico.*

Ranges for estimated fire fatalities are developed for firestorms and group fires initiated by conventional weapons in German cities during World War II. Firestorm fatalities are estimated to vary between 4% and 20% of the population-at-hazard. Group fire fatalities are estimated to include up to 4% of the population-at-hazard. Limitations on extension of these estimates to the nuclear case and to U. S. cities are discussed.

WA2.7 *Emergency Operations Research at SDC, TERENCE P. HANEY, *System Development Corporation, Santa Monica, California.*

Over the past four years, System Development Corporation has conducted several interrelated research and development activities in the area of emergency operations. The most recent applied research efforts into emergency operations have dealt with the determination of information requirements for local level executive decision-making in a nuclear disaster. These experiments have involved city managers and their executive staffs from six cities in the 100,000 population class. A number of successful experiments indicated that the concept of simulation, developed earlier for use in Air Force development and training activities, could indeed be adapted to civil defense problems. The Emergency Operations Research Center was thus established. As a result of the executive staff experiments, a number of conclusions have become evident relating to the information required by local level executives in order for them to make adequate decisions in an emergency. Assuming the appropriateness of the inputs provided to stress the displays, this manner of presenting information was not very meaningful. It was found that the operations simulation technique, if properly applied, can be substantially beneficial as an applied research tool.

WA3 Application of Operations Research to Education (Panel). Session chaired by ALEX M. MOOD, *U. S. Office of Education, Washington, D. C.*

The panel will review and discuss current applications of analysis to educational problems. These include such things as input-output models of the educational system as a production process, flow models, models of individual institutions, evaluation models using regression models, analyses of education as a long term investment, program budgeting in education.

WP1.1 *Sensitivity of Optimal Inventory Policies, RAUL ALVAREZ, *Industrial Engineering Department, North Carolina State University, Raleigh, North Carolina.*

The sensitivity of the optimal cost of an inventory system to the various parameters involved in its determination is defined as follows:

$$S=\frac{(\text{change in cost})/(\text{cost})}{(\text{change in parameter})/(\text{parameter})}$$

or

$$S=\frac{\partial C_0}{\partial P}\cdot\frac{P}{C_0}\quad .$$

This is a unitless parameter. This paper shows how the sensitivity of the parameter is determined for a number of deterministic and probabilistic models. In almost all cases these are very simple expressions. With the aid of a computer, tables have been developed and graphs drawn that permit one to find, knowing the inventory model, the sensitivity of the cost to each of the parameters. The models investigated cover a small portion of the possible inventory systems encountered in actual situations. They are shown here with the purpose of showing how neat the expressions are and also how sensitivity behaves for different models.

WP1.2 *A Demonstration in the Use of Operations Research in the Improvement of a Hosiery Fabric, D. J. MOFFIE and GEORGE E. NICHOLSON, JR., *University of North Carolina, Chapel Hill, North Carolina.*

The major purpose of this project was to determine the optimum combination of factors for the production of a welt in ladies seamless hose which would meet the established physical and aethestic characteristics established by the Company. A composite second order design was used in the experiment. Ten stockings were prepared for each setting. These were evaluated by quality control personnel. A rating form which included dimensions of ribbiness, sleaziness, crinkles and overall appearance was used by the judges. Five variables were studied. These were: (1) welt length; (2) yarn type; (3) yarn twist; (4) setting temperature of the yarn; (5) cam setting. Optimum combinations were secured by a number of methods but the most practical solutions were secured through analysis of surfaces generated. The design was orthogonal. Findings supported experimentation conducted by the Company.

WP1.3 *Simulation Techniques Used as Aids for Decision Making, ALBERT W. BARTGES, *Systems and Procedures, Textile Fibers Department, E. I. du Pont de Nemours and Company, Inc., Wilmington, Delaware.*

The Textile Fibers Department is one of the eleven operating departments of the Du Pont Company. This is a multi-plant and multi-fiber operation which is expanding rapidly. Quantitative answers are continuously needed for the evaluation of proposed courses of action. This presentation will deal with the application of linear programming and a machine and production scheduling computerized program as simulation techniques for attaining quantitative answers to alternate courses of action relative to costs, earnings, labor requirements, equipment utilization, inventory levels and product mix.

WP2.1 The Application of Simulation to Civil Defense System Development and Training, LARRY J. WELLS, *Stanford Research Institute, 333 Ravenswood Avenue, Menlo Park, California.* (Sponsored by ROBERT S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*)

A simulation model has been formulated to assist the Office of Civil Defense in the development of planning and operating criteria for Emergency Operating Centers and in the training of local government officials for the management of survival resources in a disaster environment. The model consists of two parts, a computer simulation and a real-time simulation. The inputs to the computer model are the physical characteristics of a city or county, the locations of critical resources, and postulated attack patterns. The computer develops a disaster environment and generates a time-phased series of emergency problems and informational reports. The computer outputs then become inputs to a real-time simulation in which local government officials are presented with a realistic test of their direction and control system. Real-time simulation enables an investigation of the dynamic responses of participants to a constantly changing environment. An analysis of the simulation provides data on the effectiveness of various direction and control system configurations, information processing techniques, and decision-making procedures. Because of the speed, simplicity, and economy with which a realistic disaster environment can be simulated on a computer the model is applicable for training as well as system development.

WP2.2 NRDL Target Vulnerability Studies as Applied to the Civil Defense Program, JUNE BREVDY, *Countermeasures Evaluation Branch, U. S. Naval Radiological Defense Laboratory, San Francisco, California.*

The Office of Civil Defense (OCD) is sponsoring a study at NRDL in which the focus will be on predicting the postattack survivability of a city. This study is based on previous work for a Navy project (the Target Vulnerability Studies) and will have the same general objectives: (1) to provide a means for estimating, rapidly and consistently, the effects of a widespread continental nuclear attack on facilities and personnel; (2) to provide an evaluation of the capability of these effects to interfere with operations; (3) to provide estimates of the time required for emergency recovery; and (4) to make recommendations for preattack actions that could alleviate the degrading effect of the attack upon designated postattack functions. The paper will discuss the approach that was designed to analyze installations of interest and the model that was constructed to provide results to satisfy the above objectives. It will also discuss the application of the method and the models to the OCD project.

WP2.3 A System Design for Developing Fallout Shelter in New Construction, E. L. HILL, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by ROBERT S. TITCHEN, *Research Triangle Institute, Durham, North Carolina.*)

There is a need to develop dual purpose fallout shelter in addition to that already identified in the National Fallout Shelter Survey. An incentives program is under consideration under which a building owner would be offered a small financial incentive to include fallout shelter beyond that inherent in "typical" designs. Additional shelter could be had by employing no cost or low cost design modification ("slanting") already developed by the Office of Civil Defense. The purpose of the study reported here is to evaluate alternative incentive programs in terms of fallout shelter added to the inventory beyond that which would have appeared spontaneously, and to estimate the costs. The research has been approached through: (1) analyzing existing structures to estimate cost and yield of added spaces through slanting for various building classes; (2) fictitious building analysis as in (1); (3) correlation of past construction history from F. W. Dodge Company reports to forecast construction rates of eligible structures in shelter deficit areas. Many additional factors are considered including: impact on building owners who have already licensed their buildings for public shelter; fringe benefits of an incentives program such as increased public awareness; the management system required, etc. The output of the study are recommended plans: (1) a program to maximize information obtained in a pilot program; (2) a program to maximize shelter added in the event that the pilot program is bypassed.

WP2.4 An Algorithm for Maximizing Cost Effectiveness of Civil Defense Shelter Development Programs, P. S. McMullan and Stanley Trustman, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by Robert S. Titchen, *Research Triangle Institute, Durham, North Carolina.*)

Civil Defense shelter development planners in the Office of Civil Defense seek maximum cost effectiveness. To this end, a computerized model has been developed for optimizing civil defense shelter development programs which build on the current National Fallout Shelter Survey. The model is risk-oriented: with a specified attack, a probability of survival is calculated for existing shelter and new shelter options. Vulnerability to both blast and fallout is considered. Input data are cost, personnel vulnerability, number of shelter spaces for both existing shelter and new shelter options, and a budget. The model then assigns population to new shelter options in a manner to maximize survivors (or uninjured survivors) for the specified budget. The output is the optimum shelter development program. Curves of survivors added, and marginal costs, as a function of budget are also obtained by varying the budget constraint. Because existing algorithms cannot handle problems of the size encountered in national analyses, a new optimizing algorithm was developed and programmed. It is suitable for transportation-type problems having a special cost matrix structure; the costs must be ordered to vary monotonically within each column.

WP2.5 An Analytical Technique for Urban Casualty Estimation from Multiple Nuclear Weapons, J. J. Hunter, *Research Triangle Institute, Durham, North Carolina.* (Sponsored by Robert S. Titchen, *Research Triangle Institute, Durham, North Carolina.*)

Currently, national vulnerability analyses of urban populations are made by assessing small grids. For many purposes, this procedure is too costly in computer time. As a tool for sensitivity analysis of national vulnerability assessment methods, an analytical technique has been developed which estimates casualties from multiple nuclear weapons. This is done by describing the urban population by a circularly symmetric spatial density function. This density function may be readily varied to describe alternative shelter postures, evacuation, etc., and for parametric analyses of many kinds. The input data are: (1) coordinates of the DGZ's and of the population center; (2) weapon yields, burst heights, shielding posture, and corresponding casualty curves; (3) CEP; and (4) two spatial population distribution parameters. The model has been programmed in FORTRAN and is now in use in sensitivity analyses for the Office of Civil Defense.

WP3.1 *The Analytic Models for Implementing the Economic Impact Studies for the Northeast Corridor Transportation Project, S. H. Putnam, *CONSAD Research Corporation, Pittsburgh, Pennsylvania.*

The Northeast Corridor Transportation Project being conducted by the U. S. Department of Commerce has been defined as a comprehensive regional transportation planning activity to determine passenger and freight requirements in that region to 1980 and beyond. As part of the total Corridor Project, CONSAD is developing a set of models to project and evaluate the economic and demographic impacts of changes in the regional transportation network. The model system is comprised of three basic submodels: 1) inter-regional, inter-industry model, 2) intra-regional allocation model, and 3) impact evaluation model. This paper discusses the theoretic and pragmatic considerations which determined the design of each of the three sub-models, the problems entailed in calibrating the models, and the strategy and progress of the effort to implement them.

WP3.2 *Econometric Study of the Urban Traffic, JACQUES FEDERWISCH and PIERRE VAN LEEUW, *Société de Recherche Opérationnelle et d'Economie Appliquée, Brussles 5, Belgium.*

The mathematical models of urban traffic are numerous and generally analyse the volume and the nature of the movements as well as the loss of time (estimated either in time or monetary units). The authors have introduced two complementary traffic sub-models (the descriptive and the explanatory one) and a new variable called displacements entropy, measuring in a defective and uniform way for all the transportation models the infrastructure possibilities existing at a given origin for reaching a given destination. The general model, completed in this manner by the description of the infrastructures making those displacements possible, brings a solution to all traffic problems in an exhaustive way. The model is also based on the prospective evolution of displacements. All the aspects can thus be studied (gain of time, cost of infrastructure, compared advantages, investments return, etc.). This model was adjusted and tested during two general urban traffic studies, which took place in Antwerp and Ghent, Belgium, including their respective suburbs. It led to the most appropriate layout for an intended underground railway network.

WP3.3 *An Investigation of Aircraft Collision Risks over the North Atlantic, LEONARD STACHTCHENKO, *Unica Research Company, Montreal, Quebec, Canada.*

This paper reviews the navigation errors of westbound aircraft traveling over assigned tracks of the North Atlantic regions. These errors have been measured by radar from the Canadian North Atlantic Air Traffic Center at Gander, Newfoundland. An analysis of the errors shows that these are not Gaussian. A theory is developed to evaluate the probability of collision over the North Atlantic region, with consideration being given to the effects of lateral separation of pre-assigned tracks.

WP3.4 *A Transportation Program for Filling Idle Classrooms in Los Angeles, T. A. BROWN, *The RAND Corporation, Santa Monica, California.*

During the 1965–1966 school year more than 25,000 elementary school children were on short, double or extended sessions in Los Angeles; at the same time there were 327 idle elementary classrooms in Los Angeles. In an effort to relieve this situation and at the same time alleviate defacto segregation the Transport-A-Child Foundation proposed last spring that the Los Angeles School Board provide transportation for more than 2000 children outside their immediate neighborhoods. Operations analysts designed a program which would cost about 67¢ per child per day. This talk will explain how this was done and mention some of the political consequences of the proposal.

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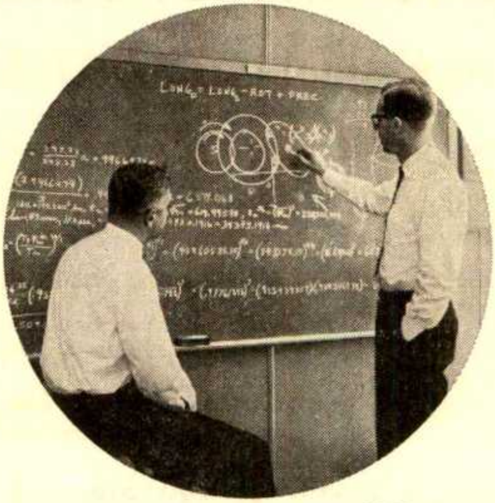

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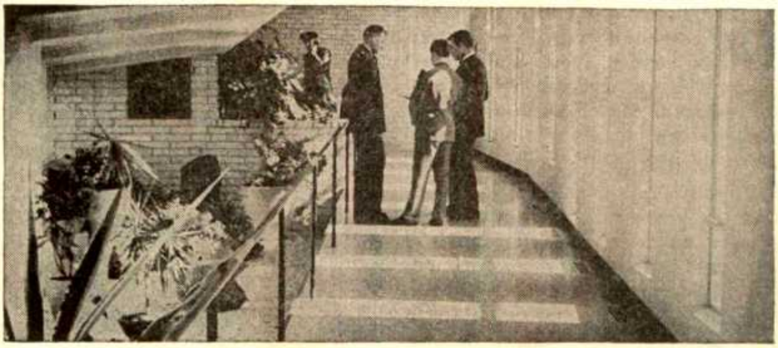

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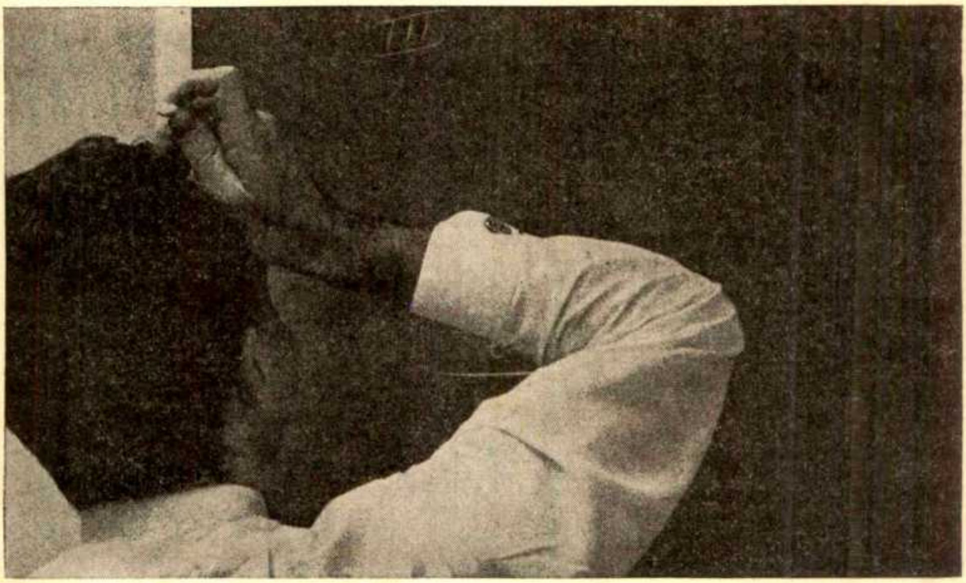

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Please check the listed areas of career opportunity at ORI. If you are experienced in one or more of them and hold a degree (preferably advanced) in engineering, science, mathematics/statistics or economics, we would like to hear from you. You may send your resume in complete confidence to: Mr. Carlton Robinson, Professional Staffing Operations Research Incorporated, 1400 Spring Street, Silver Spring, Maryland (suburb of Washington, D. C.). An equal opportunity employer M&F.

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We have had numerous positions listed with us for Operations Research Managers for companies which DO NOT NOW HAVE O.R. ACTIVITIES. These are all industrial manufacturing and/or service companies, prominent nationally, varying from a sales volume of about $50,000,000 to several hundred millions. They include manufacturers of steel products, petro-chemicals, food products, chemicals, electronics, and merchandising. Locations include: Boston, New York, New Jersey, Eastern Penna., Milwaukee, Dallas, Michigan, Minneapolis, and other Midwestern and Eastern locations. Essentially the requirements are about the same in all the positions. The people they seek will either have been in managerial or project leader capacity, and will have been responsible for some conceptualization as well as development and implementation of OR/MS programs. Since they are brand new positions, there are exceptional opportunities. $15,000–$22,000.

R-908A-6 MANAGER-ADVANCED TECHNOLOGY $25,000-$30,000 +

R-908B-6 MANAGER-OPERATIONS RESEARCH $20,000-$25,000 +

R-908C-6 SENIOR OPERATIONS RESEARCH ANALYSTS $17,000-$23,000 +

East. Activities currently aerospace centered, involving both NASA and military problems. There is also "a certain degree of growing interest in exploring the company's possible role re 'great society' programs." The manager of O.R. will report to the manager of Advanced Technology. Both will have PhD's in "hard sciences', the latter being broader in scope, and with proven managerial backgrounds.

SPECIAL NOTE

Of necessity, we have had to limit the number of positions described herein to only a few of the many positions we are seeking to fill. We simply have too many openings to do justice to them all, particularly in the junior and intermediate levels, ranging from about $10,000 to $18,000. These include every conceivable type of business organization including the small and the large company, the newly established and well established departments, etc. These requirements are in and near New York City, Newark, Boston, Philadelphia, Pittsburgh, Washington, D. C., Atlanta, Chicago, Cleveland, St. Louis, Kansas City, Omaha, Milwaukee, Minneapolis, Houston, Dallas, Los Angeles, San Francisco, Tacoma, Seattle, Akron, Dayton, Toronto, Phoenix, London, Paris, Melbourne, Japan, Germany, Holland, Canada, et al.

Accordingly, anyone seriously interested in any of the positions listed, or in any opportunities in the fields of operations research, management information systems, the management sciences, economics, econometrics, mathematics, statistics, data processing, and the public sciences... whether regarding industrial or military applications, including non-profit research groups is invited to contact us.

All inquiries will be treated confidentially. ALL OUR CHARGES ARE ASSUMED BY EMPLOYER CLIENTS. All interested parties are invited to send us a detailed experience resume which should include position objective, current salary, salary requirements, geographic preferences, and areas which will not be considered.

YOUR REFERRALS WILL BE APPRECIATED

We will be in attendance at the ORSA Meeting Oct. 17–19, 1966, at the Jack Tar Hotel, Durham, N. C.

We will be interviewing in London, England—October 3–7, 1966.

Candidates who can get their resumes to us prior to this meeting, and particularly those who intend to attend, will facilitate our arranging interviews with senior management personnel of these clients.

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